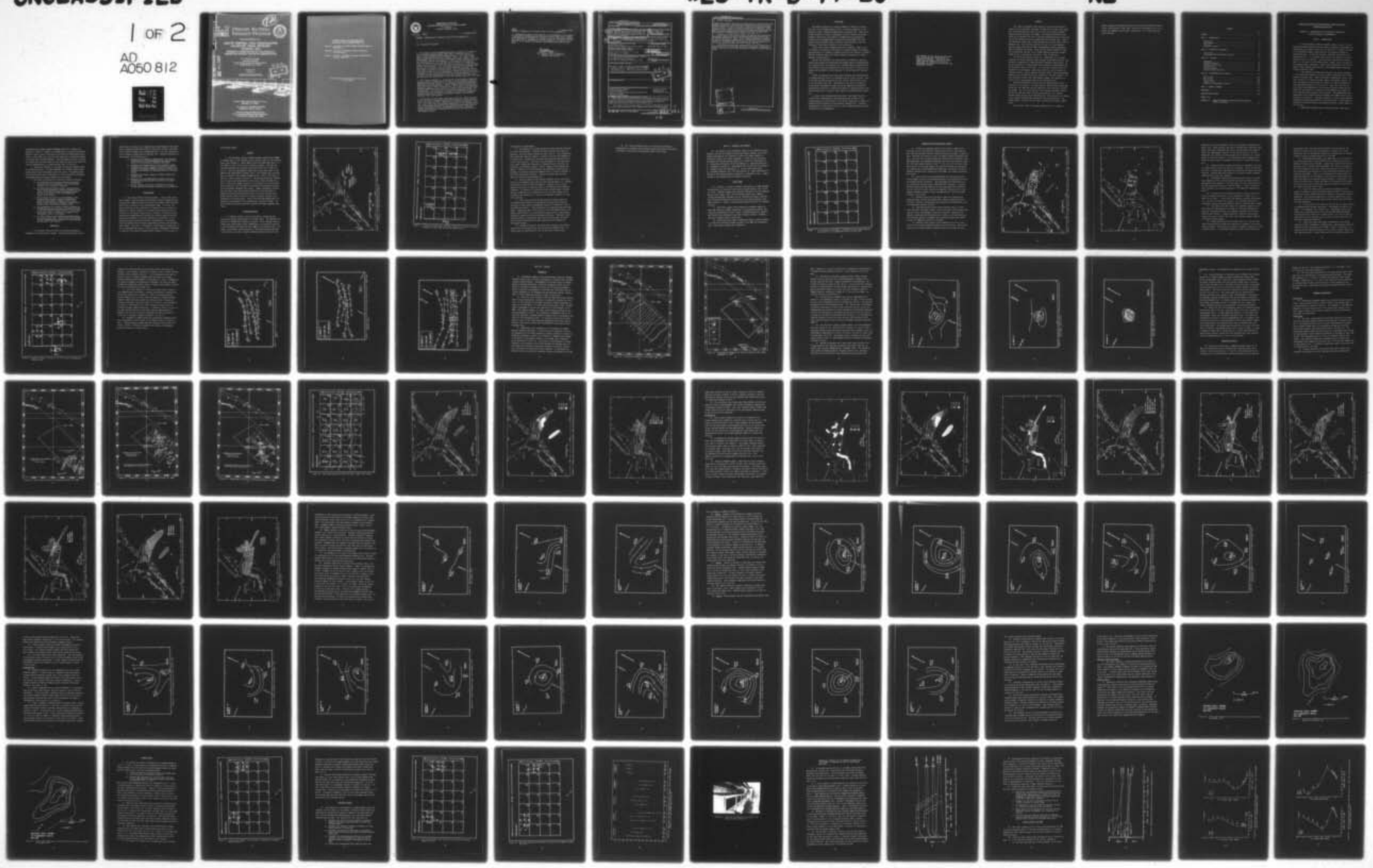
AD-A050 812 MOODY COLL OF MARINE SCIENCES AND MARITIME RESOURCES --ETC F/G 13/2
AQUATIC DISPOSAL FIELD INVESTIGATIONS, GALVESTON, TEXAS, OFFSHO--ETC(U)
DEC 77 E L ESTES, R J SCRUDATO DACW64-75-C-0069

UNCLASSIFIED WES-TR-D-77-20 NL

1 OF 2
AD
A050 812



12 B.S.

DREDGED MATERIAL RESEARCH PROGRAM

TECHNICAL REPORT D-77-20

AQUATIC DISPOSAL FIELD INVESTIGATIONS GALVESTON, TEXAS, OFFSHORE DISPOSAL SITE

APPENDIX A: INVESTIGATION OF THE HYDRAULIC REGIME AND PHYSICAL NATURE OF SEDIMENTATION

by

E. L. Estes, R. J. Scrudato
Texas A&M University
Moody College, Department of Marine Sciences
College Station, Texas 77843

December 1977

Final Report

Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

Under Contract No. DACW64-75-C-0069
(DMRP Work Unit No. 1A09A)

Monitored by Environmental Effects Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

AQUATIC DISPOSAL FIELD INVESTIGATIONS,
GALVESTON, TEXAS, OFFSHORE DISPOSAL SITE

Appendix A: Investigation of the Hydraulic Regime and Physical Nature of Sedimentation

Appendix B: Investigation of Water-Quality Parameters and Physicochemical Parameters

Appendix C: Investigation of the Effects of Dredging and Dredged Material Disposal on Offshore Biota

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
P. O. BOX 631
VICKSBURG, MISSISSIPPI 39180

IN REPLY REFER TO: WESYV 31 December 1977

SUBJECT: Transmittal of Technical Report D-77-20 (Appendix A)

TO: All Report Recipients

1. The technical report transmitted herewith represents the results of one of several research efforts (work units) undertaken as part of Task 1A, Aquatic Disposal Field Investigations, of the Corps of Engineers' Dredged Material Research Program. Task 1A is a part of the Environmental Impacts and Criteria Development Project (EICDP), which has as a general objective determination of the magnitude and extent of effects of disposal sites on organisms and the quality of surrounding water, and the rate, diversity, and extent such sites are recolonized by benthic flora and fauna. The study reported herein was an integral part of a series of research contracts jointly developed to achieve the EICDP general objective at the Galveston, Texas, Disposal Site, one of five sites located in several geographical regions of the United States. Consequently, this report presents results and interpretations of but one of several closely interrelated efforts and should be used only in conjunction with and consideration of the other related reports for this site.

2. This report, Appendix A: Investigation of the Hydraulic Regime and Physical Nature of Sedimentation, is one of three contractor-prepared appendices published relative to the Waterways Experiment Station Technical Report D-77-20 entitled: Aquatic Disposal Field Investigations, Galveston, Texas, Offshore Disposal Site. The titles of all contractor-prepared appendices of this series are listed on the inside front cover of this report. The main report will provide additional results, interpretations, and conclusions not found in the individual contractor-prepared reports and provide a comprehensive summary and synthesis overview of the entire project.

3. The purpose of this study, conducted as Work Unit 1A09A, was to determine the fate of dredged material after deposition in the disposal site. The report includes a discussion of currents, bathymetry, critical erosion velocities, and sediment composition in the vicinity of the site. The sediment distribution was determined through grab sampling, coring, subbottom profiling, and bathymetric surveys. Laboratory studies were conducted to determine the erosional characteristics of the dredged material.

WESYV 31 December 1977
SUBJECT: Transmittal of Technical Report D-77-20 (Appendix A)

4. Although the reader is cautioned as to the usefulness of the authors' conclusions and interpretations, the data in their input will be useful in determining the placement of dredged material for open-water disposal. This could lead to optimization of either dispersal or retention of the material as a technique for maximum environmental protection at this site.

JOHN L. CANNON
Colonel, Corps of Engineers
Commander and Director

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report D-77-20 ✓	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 6 AQUATIC DISPOSAL FIELD INVESTIGATIONS, GALVESTON, TEXAS, OFFSHORE DISPOSAL SITE; APPENDIX A: INVESTIGATION OF THE HYDRAULIC REGIME AND PHYSICAL NATURE OF SEDIMENTATION.		5. TYPE OF REPORT & PERIOD COVERED 9 Final report.
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) 10 E. L. Estes R. J. Scrudato 15 DACW64-75-C-0069		8. CONTRACT OR GRANT NUMBER(s) Contract No. DACW64-75-C-0069 New.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Texas A&M University Moody College, Department of Marine Sciences College Station, Texas 77843		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS DMRP Work Unit No. 1A09A
11. CONTROLLING OFFICE NAME AND ADDRESS Office, Chief of Engineers, U. S. Army Washington, D. C. 20314		12. REPORT DATE 11 December 1977
		13. NUMBER OF PAGES 155 12 162p.
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) U. S. Army Engineer Waterways Experiment Station Environmental Effects Laboratory P. O. Box 631, Vicksburg, Mississippi 39180		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

18 WES 19 TR-D-77-20

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dredged material disposal
Field investigations
Galveston Offshore Dredged Material Disposal Site
Geologic processes
Geological sedimentation
Hydraulic regimen
Sedimentation
Waste disposal sites

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents the results of a multifaceted investigation of the geological processes of deposition, erosion, and transport of dredged material within the area of the Galveston offshore Dredged Material Disposal Site (DMDS) during the period 6 March 1975-20 November 1976.

This study involved two major phases: a pilot study designed to rapidly survey the DMDS and environs, and an experimental study to delineate natural

(Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

New 410 591

JOB

20. ABSTRACT (Continued).

changes in the physical and geological characteristics of the study area after disposal had occurred. The latter study involved the monitoring of dredged material disposal at selected locations to determine the physical-geological processes active. Control sites were also monitored for comparison. Hydrographic data were collected to delineate current and wave effects within the DMDS, and flume experiments were conducted to determine the hydrodynamic characteristics of dredged material placed in the area.

Comparisons are made between sediment and carbonate concentrations and bathymetric differences evident from data collected during the pilot and postdisposal phases of the study. The differences determined are discussed in light of the hydraulic regime present. Estimates of current velocities required to redistribute DMDS bottom sediments are based on comparisons between flume experiment studies and on-site current meter data.

Available data indicate that dredged material has been eroded from the shallow water portion of the DMDS and has been transported in a downcoast-offshore direction; little erosion was noted in the deeper, offshore disposal sites.

DISCLAIMER

The primary objective of Contract DACW64-75-C-0069 was to determine the fate of dredged material after it had been deposited in the Galveston, Texas, offshore dredged material disposal site. This was to include studies of currents, bathymetry, critical erosion velocities, sediment composition, and pathways of dredged material dispersion. Personnel of the Dredged Material Research Program (DMRP) feel that several factors should be kept in mind by those desiring to use the findings of this study as stated in the conclusions.

First, very little predisposal data were obtained. Hence, it is not possible to ascertain conclusively if observed changes in sediment characteristics at a number of sampling stations were related to dredged material disposal rather than normal seasonal fluctuations in these sediment characteristics.

Second, the contractor was unsuccessful in attempts to develop a quantitative method for differentiating dredged material sedimentological characteristics from disposal site sedimentological characteristics. This problem is further complicated by the contractor's failure to use appropriate bathymetric aids during much of the postdisposal sampling effort.

Third, the physical data base used in analysis and interpretation of dredged material effects is inadequate due to several factors. Much of the data obtained during the initial contract period either could not be verified or was lost. Additionally, the failure to adhere to the specified experimental design during the immediate postdisposal investigation resulted in insufficient numbers of sampling stations and sample replication to evaluate acute impacts of dredged material disposal.

In view of the problems described herein, the reader should be cautious when considering the appropriateness and validity of the interpretations and conclusions of this report regarding the impacts of dredged material disposal at the Galveston disposal site. Likewise, extrapolation of these study results to other dredged material disposal operations is not recommended.

THE CONTENTS OF THIS REPORT ARE NOT TO BE USED FOR ADVERTISING, PUBLICATION, OR PROMOTIONAL PURPOSES. CITATION OF TRADE NAMES DOES NOT CONSTITUTE AN OFFICIAL ENDORSEMENT OR APPROVAL OF THE USE OF SUCH COMMERCIAL PRODUCTS.

PREFACE

This report represents study results of a multi-faceted investigation of the geological processes of deposition, erosion, and transport of dredged materials within the area of the Galveston offshore Dredged Material Disposal Site (DMDS). The primary objective of the study was to determine the fate of disposed dredged materials within the area of the offshore Galveston Dredged Material Disposal Site. Field and laboratory studies were conducted during the period 6 March 1975-20 November 1976. The study was monitored by the U. S. Army Engineer Waterways Experiment Station (WES), Environmental Effects Laboratory (EEL), Vicksburg, Mississippi, under Contract Number DACW64-75-C-0069. The investigation was part of the Dredged Material Research Program (DMRP) which is sponsored by the Office, Chief of Engineers.

The report was written by Drs. E. L. Estes and R. J. Scrudato, Department of Marine Sciences, Moody College, Texas A&M University, and contains a compilation of data provided by numerous investigators. Dr. Arnold Bouma and Dr. George Huebner were coprincipal investigators for the geological phase of the study. Dr. Gary Hall, formerly with the Department of Oceanography, Texas A&M University, was the project coordinator; Messrs. Anthony Moherek and Bruce Sidner, Texas A&M graduate students, were involved with field, laboratory, and data analyses. Mr. Dale Coulthard, former Texas A&M graduate student, was primarily involved with the predisposal phase of the geological study.

Numerous individuals assisted with the compilation and interpretation of this report. Dr. Donald Harper, Moody College, Texas A&M University, provided many helpful suggestions and critically reviewed all drafts. Ms. Vicki Tyson and Ms. Lynda Cashiola patiently contributed their time and expert secretarial assistance. Mr. Charles Coleman, Moody College, Texas A&M University, was involved in all phases of the report including data compilations and interpretations. Dr. Thomas Wright, technical monitor (EEL), provided many helpful suggestions.

The study was under the general supervision of Dr. Robert M.

Engler, Manager, Environmental Impacts and Criteria Development Project, and Dr. John Harrison, Chief, EEL. During the investigation, Col. J. L. Cannon was Commander and Director of WES and Mr. F. R. Brown was Technical Director.

CONTENTS

AQUATIC DISPOSAL FIELD INVESTIGATIONS, GALVESTON, TEXAS, OFFSHORE DISPOSAL SITE

APPENDIX A: INVESTIGATION OF THE HYDRAULIC REGIME AND PHYSICAL NATURE OF SEDIMENTATION

PART I: INTRODUCTION

1. The Environmental Effects Laboratory (EEL) of the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, has established four regional study sites in coastal U. S. waters to assess the environmental impacts associated with the offshore disposal of dredged material. In the Gulf of Mexico, Galveston was chosen as the experimental site. In the Great Lakes region, the research site was at Ashtabula, Ohio, in Lake Erie. Two sites were located on the Pacific Coast: at the mouth of the Columbia River, Oregon, and at the mouth of the Duwamish River, Washington. These field studies were a part of the Aquatic Field Disposal Investigation of the Dredged Material Research Program conducted by WES.

2. The economies of Houston and Galveston are greatly dependent on the unrestricted movement of vessel traffic through the ship channel system in Galveston Bay. Annual maintenance dredging must occur in the outer reaches of the channel system, namely, the entrance channel, the outer bar channel, and the inner bar channel, to keep the channels at their authorized depths of 12.0 to 12.5 m. Sand, silt, and clay are continually being deposited by tidal currents flowing through Bolivar Roads, and an average of 1.42 million m^3 of sediment are removed each year from these three portions of the channel. The dredged material is transported to the Dredged Material Disposal Site (DMDS) offshore from Galveston and released.[1] Galveston represents a fairly typical channel maintenance problem representative of the Gulf Coast: large volumes of sediments are dredged annually and disposed offshore in water depths of 15 m or less.

3. Maintenance dredging prior to and during this study was ac-

complished by the hopper dredge McFARLAND, which has a single load capacity of 2294 m^3. Dredging is accomplished by lowering side-mounted, hydraulic suction arms to the channel bed while the dredge moves ahead slowly. Loose sand, silt, and clay are sucked into the head and pumped into hopper bins located amidships. When the hoppers are full, the arms are raised and the dredge steams to the offshore disposal site where the load of dredged material is vented through doors in the hull.

4. Maintenance dredging is necessary to maintain shipping access to Galveston Bay ports. If left undredged, the entrance channel would quickly shoal and be unnavigable within two years. The primary objective of this project was to determine if, and to what extent, dredging and dredged material disposal affected the environment.

5. The report is divided into five major sections including:

a. An introduction that discusses dredging operations, objectives of the investigation, the study design, location, and a review of literature.

b. The materials and methods section, which discusses the field and laboratory procedures followed for the study. This section reviews the methods followed for the pilot study and pre- and postdisposal phases of the project.

c. The discussion of results of the bathymetry, subbottom seismic surveys, sediment distributions, carbonate distributions, sediment tracer experiments, remote sensing, the hydraulic regime and the currents within the DMDS and adjacent areas.

d. The interpretation of results section discusses the sedimentological and carbonate concentration changes at the three disposal sites (buoys B, C, and D) and two control sites. In addition, a summary of the hydrographic results is presented.

e. A review of many of the problems encountered during the course of the study. This section also proposes several recommendations regarding the overall design and operation of the project.

Objectives

6. The Galveston study was tripartite involving geological, biological, and water-quality studies. The primary objectives of this

report were to develop a more comprehensive understanding of the physical and geological processes affecting deposition, erosion, and transport of natural sediments and dredged material in the ship channel and in the offshore dredged material disposal site. Specific objectives of this portion of the study were to:

a. Determine the bathymetry, sedimentology, and subbottom characteristics of the dredged material disposal site prior to the initiation of disposal activities.

b. Determine the characteristics of the hydraulic regime including the critical erosion velocities necessary to suspend and transport sediments, current velocities and direction, and amounts of suspended matter in the water column.

c. Determine the natural changes in sediment composition through time.

d. Determine if the dredged material mounds were being eroded through time and where the material was being transported.

e. Monitor disposal activities to determine the length of time required for ambient conditions to re-establish.

Study Design

7. This study involved two major phases: a pilot study, which was designed to rapidly survey the Galveston offshore Dredged Material Disposal Site (DMDS) and environs and the ship channel from which sediments would be removed, and an experimental study. Initially, the latter study was to have consisted of a baseline study to provide information on natural changes in the physical and geological characteristics in the general study area and, secondly, a monitoring study during which dredged material disposed at selected locations would be monitored to determine if erosion occurred at the mounds or if the mounds were being colonized by benthic invertebrates. The baseline study was deleted from the study program mainly because time and money were limited. This was, in retrospect, an unfortunate circumstance. As will be explained more fully in later sections, considerable information is lacking on the natural sedimentological changes in the vicinity of

the disposal mounds.

Location

8. The Galveston offshore Dredged Material Disposal Site (DMDS) is located about 3.8 km southeast of the southern limit of the Galveston South Jetty (Figure 1). Water depths within the DMDS range from 9.1 m near shore to 15.8 m at the site's southern boundary. The DMDS was initially divided into 28 square blocks during the pilot study (Figure 2). After the experimental study began, buoys were placed in the DMDS to mark experimental disposal sites. The intended buoy locations were the center of the boundary between blocks 1 and 2, the center of block 12, and the center of block 14. The buoy positions were checked, and, as can be seen from Figure 2, none were in their intended locations. Buoy B was located in block 8, C in block 12, and D was southeast of block 14. For the sake of consistency the following notation will be followed throughout this report. Samples designated as being from the buoy B site were actually collected in and near block 8. Samples and data collected from the buoy C site were referred to as being from the center of block 12, but were actually located to the southeast of the center point. Buoy D site data and samples were collected to the southeast of the intended site, outside the DMDS. All data reduced to map form have been corrected for proper sampling locations.

Literature Review

9. Galveston Island is part of the barrier island and spit system that borders the majority of the Texas coast. The importance of barriers to sedimentation studies is twofold. First, because they are common along coasts where active sedimentation is currently occurring, it can be assumed that they were also common in the geologic past. Secondly, most barrier islands consist of a sand body deposited between two mud facies, and such a sequence provides potential traps for the

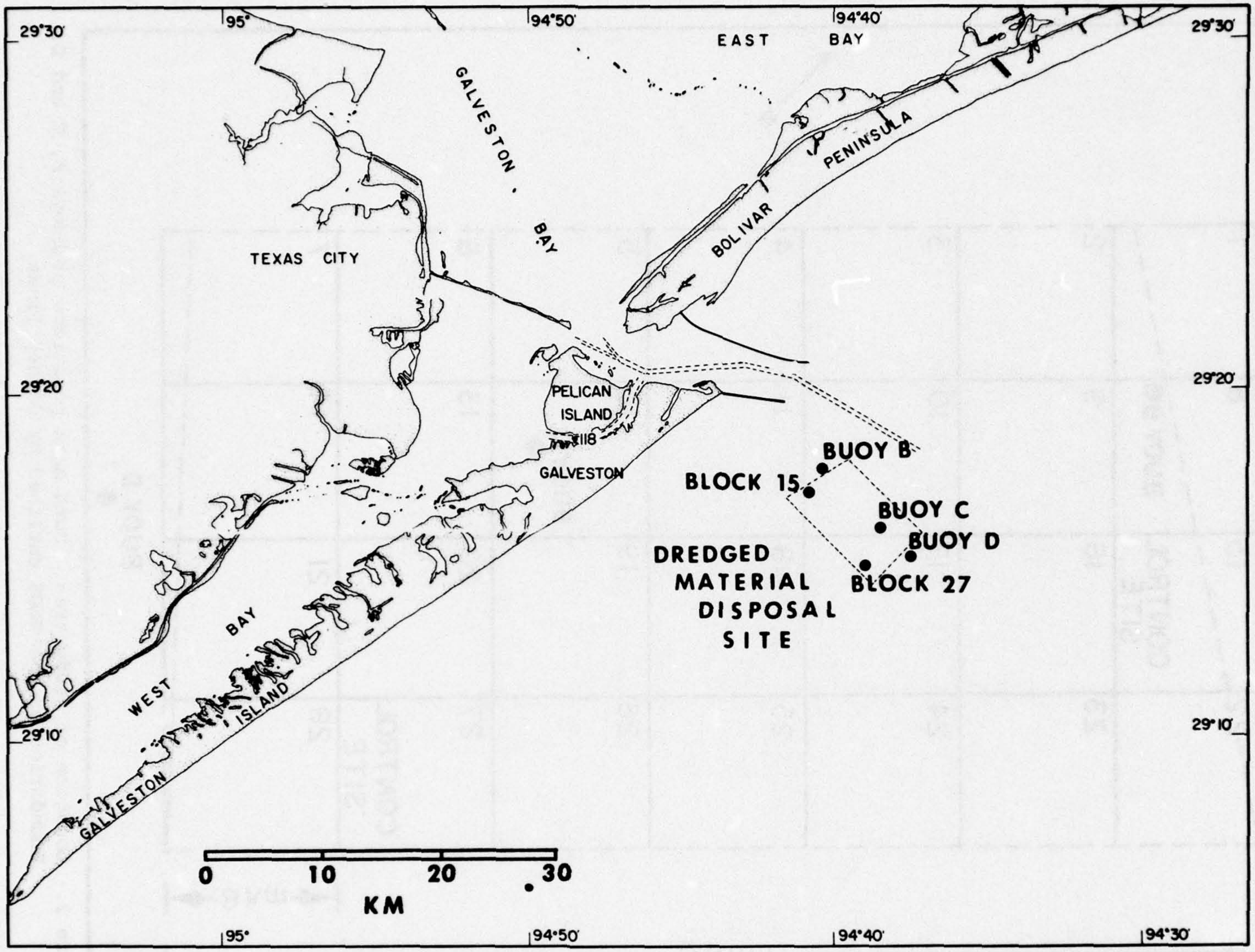


Figure 1. Location of the dredged material disposal site (DMDS) showing locations of disposal sites at buoys B, C, D and control sites 15 and 27

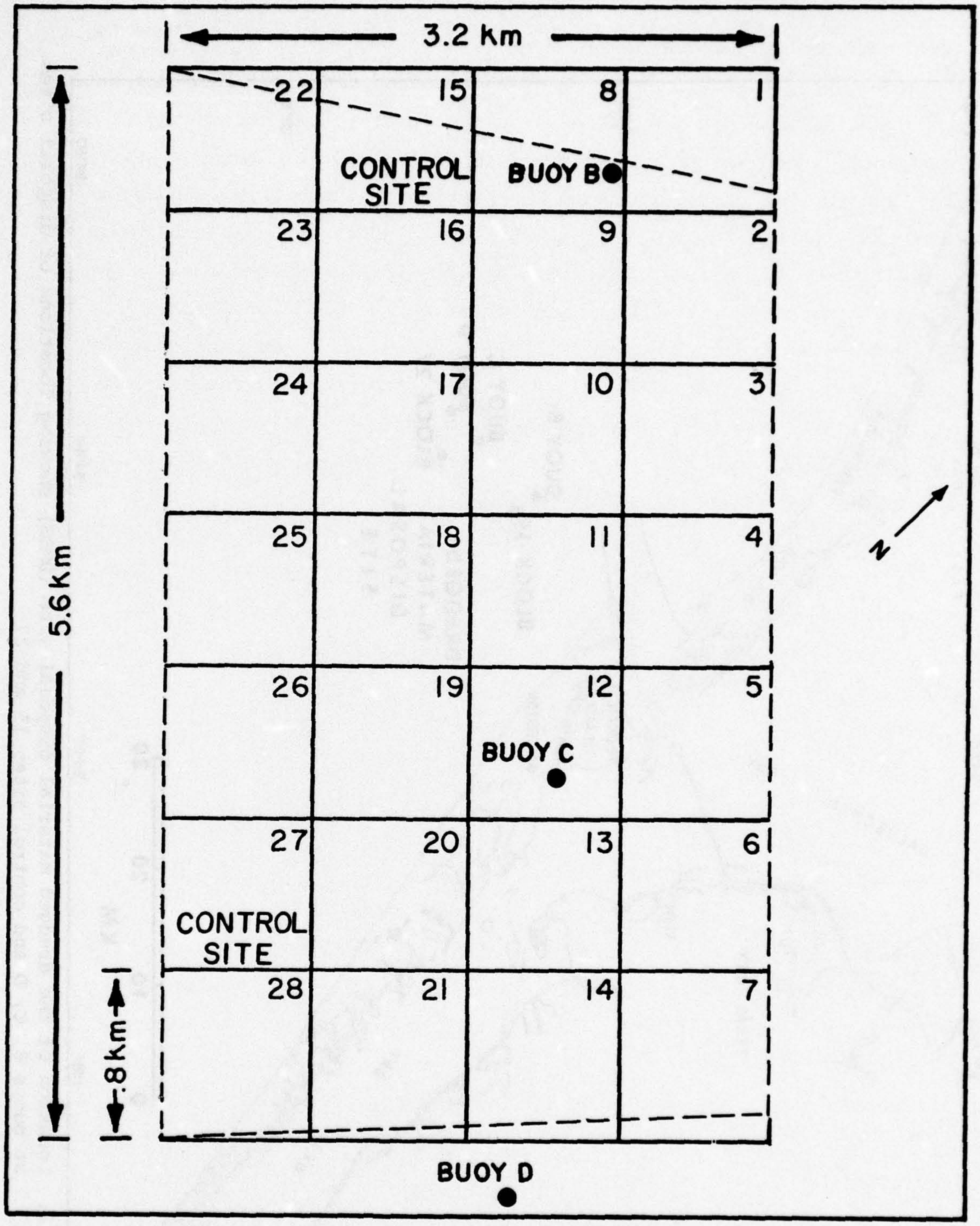


Figure 2. Location of study area. Dots mark positions of buoys B, C and D. Boundaries of the DMDS outlined by dashed lines

concentration of hydrocarbons.

10. The formation of a barrier-protected coast has been discussed by several investigators. Shepard[2] and Hoyt[3] rejected the theory of emergence, which was popular during the early 1900's.[4] Both Shepard and Hoyt stated that barriers formed in a region of either slow submergence or steady state. Shepard also discussed the different characteristics of Gulf Coast barriers. The origin and development of the Texas shoreline, which includes the formation of Galveston Island, have been described by the following authors: Henry,[5] LeBlanc,[6] and Lankford and Rogers.[7] Davies et al.[8] investigated the sedimentary structures and textures of Galveston Island and compared them to a barrier sequence in the Lower Cretaceous of Montana. From their studies they devised a model for barrier island sedimentation.

11. General studies of the surface sediments of the continental shelf in the northwest Gulf of Mexico have been published (i.e. Greenman and LeBlanc,[9] Curry,[10] Scott and Hayes[11]). However, none of these authors carried out an extensive study of the Galveston area nearshore sediments. In addition, a literature review revealed that no studies had been conducted in the Galveston area for the sole purpose of ascertaining the direction(s), velocity, and sediment transport of longshore currents.

12. The source and distribution patterns of Texas beach and continental shelf sands have been mapped and divided into distinct provinces by heavy mineral assemblages (Bullard,[12] Goldstein,[13] Hsu,[14] Van Andel and Poole[15]). Three provinces are recognized along the Texas coast. Progressing west to east these are the Rio Grande Province, the Western Gulf Province, and the Transition Zone Province (transitional between the Western Gulf and Mississippi Provinces). Galveston Island has been placed in the Western Gulf Province by Van Andel and Poole, with the main contribution of sands coming from the Colorado and Mississippi Rivers.

13. Pinsak and Murray[16] concluded from a regional clay mineral pattern that the Trinity River, which flows into Galveston Bay, is a major source of montmorillonite for the Galveston offshore area.

14. For a more thorough review of the available literature, a bibliography is included listing reference materials used by the various researchers involved with the geological phase of the study.

PART II: MATERIALS AND METHODS

15. The nature of the sedimentary regime in the dredged material disposal site and the entrance channel was largely unknown, and a multiphased investigation was initiated to obtain the maximum amount of information within the allowed timeframe. To this end, the following procedures and operations were applied by a variety of investigators: a. collection and analysis of bottom samples, b. subbottom profiling, c. bathymetric surveys, d. hydrographic data collections and analysis, e. sediment tracer determinations, f. current data collections, g. suspended sediment collection and analysis, h. flume experiments to determine the physical-hydraulic properties of sediments, and i. remote sensing of the dredged material disposal operations.

Pilot Study

16. Initially, in order to broadly characterize the DMDS sediment distributions, the area was divided into 28 square blocks, each 0.8 km on a side. Sediment samples were collected from each of the 28 sampling blocks using a spade corer (3/4-size Reineke spade corer) sampler; accurate navigational equipment was not available and sample locations were therefore determined by time-velocity runs (dead reckoning) from known locations. Figure 3 illustrates approximate locations of sampling stations.

17. Grain-size analyses were conducted on sediment samples by Texas A&M University (TAMU), Department of Oceanography personnel utilizing the methodology of Folk;[17] means, standard deviations, skewness, and kurtosis were determined using Folk's graphic methods. Sediment maps were prepared based on these data.

18. During the pilot study, a subbottom seismic survey utilizing a 3.5-kHz high-resolution system was made of the DMDS and surrounding area. Three basic horizons were identified.

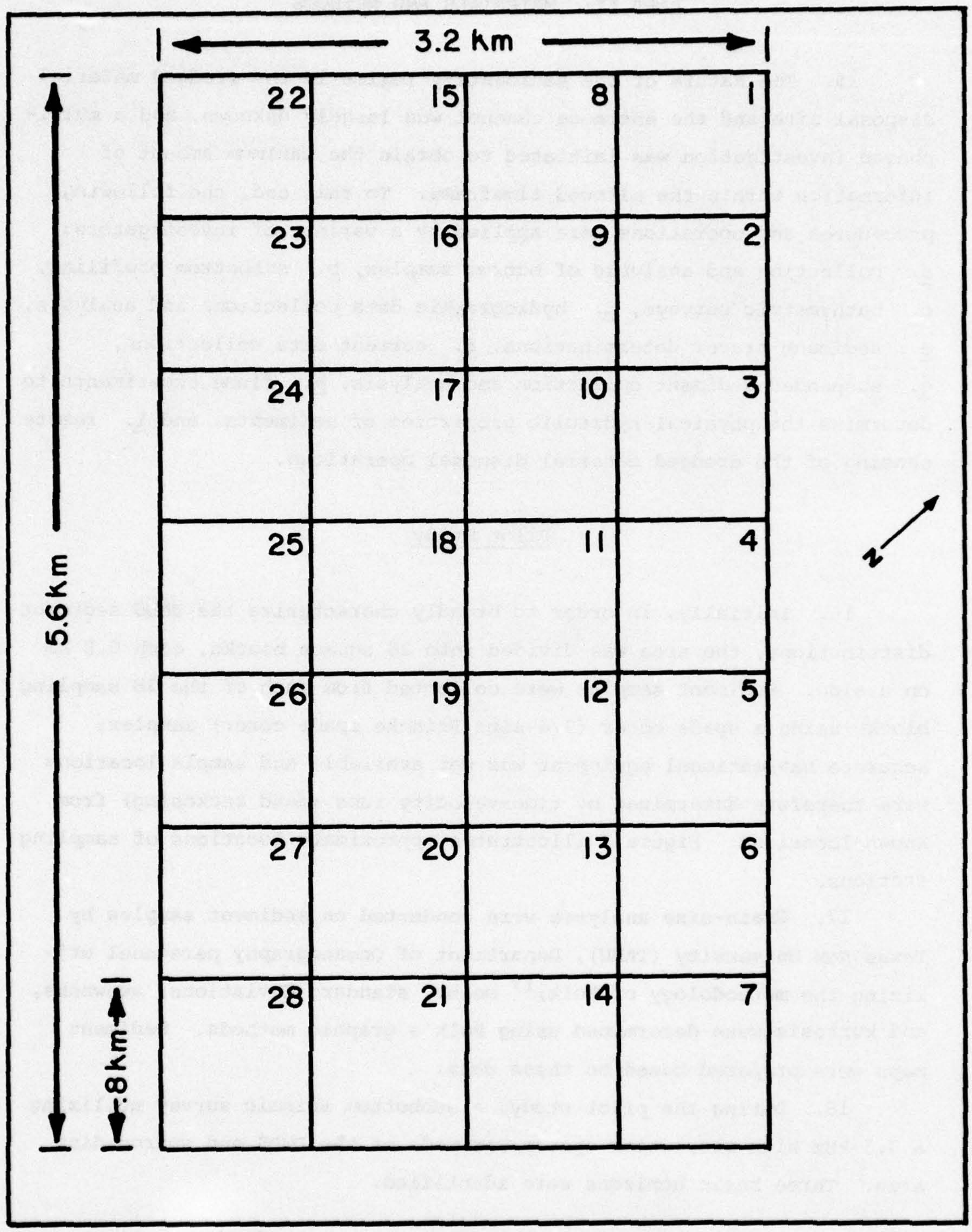


Figure 3. Block division of the DMDS. Locations of pilot study sampling stations are at the approximate center of each block

Predisposal and Postdisposal Studies

19. During the predisposal phase of the project, samples were collected with a 136-kg gravity coring device and a Van Veen grab sampler from the Galveston entrance channel system and the DMDS. Figures 4 and 5 illustrate the location of the 118 samples obtained throughout the area. Both the core and grab samples were preserved and returned to the TAMU Department of Oceanography laboratory for grain-size analysis using the sieve and pipette methods of Folk.[17] The top 10-15 cm of each core and a portion of each grab sample were used for sediment-size analysis. Core samples were X-radiographed for sedimentary structures, but due to sediment homogenization, especially in the DMDS, few primary structures were noted.

20. Heavy minerals were extracted from the sand portion of selected samples with use of bromoform separation and identified with use of standard optical procedures. Clay mineralogy was determined by X-ray diffraction analyses using a modified Grim[18] procedure. As heavy mineral analyses and determination of clay mineralogy were conducted only for the pilot study, they have no bearing on delineation of post-disposal sediment transport within the DMDS and will not be discussed further in this report.

21. Sediment grain-size distribution maps were prepared and additional maps illustrating sample mean, median, standard deviation (sorting), skewness, and kurtosis were prepared from reduced data using the statistical methods of Folk.[17]

22. Subbottom profile surveys were conducted using a 3.5-kHz high-resolution reflection system. During this phase of the study, both side scan sonar and bathymetry data were collected. Additional bathymetry information was obtained using a variety of bottom profilers, and variations between instruments were normalized using known depths outside the immediate vicinity of the DMDS.

23. Sediment tracer studies were conducted at the buoy B site (block 8) to delineate sediment transport within the area. Because the grains used to trace sediment transport within an area must be repre-

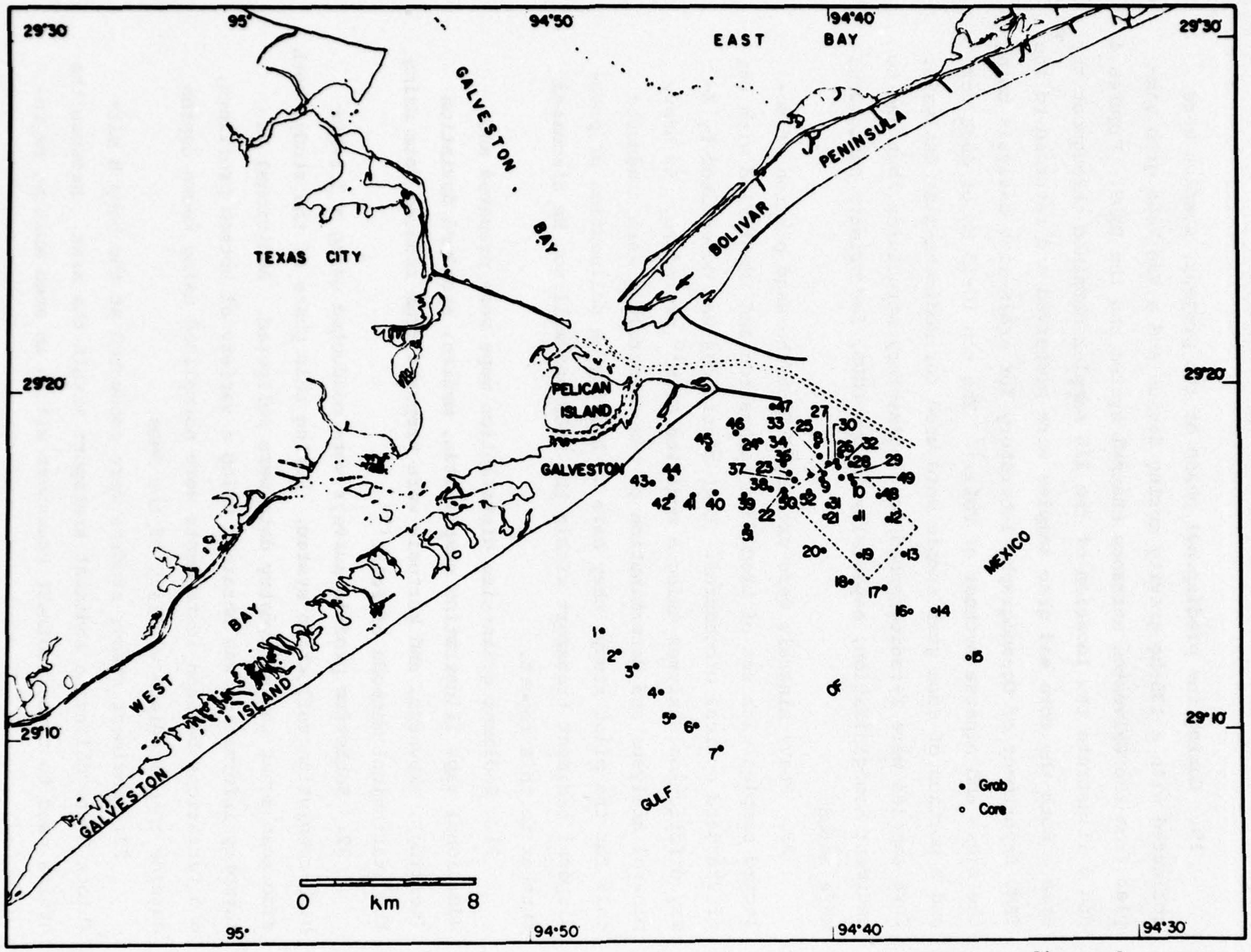


Figure 4. Location of bottom sediment samples taken within and near the DMDS; predisposal survey

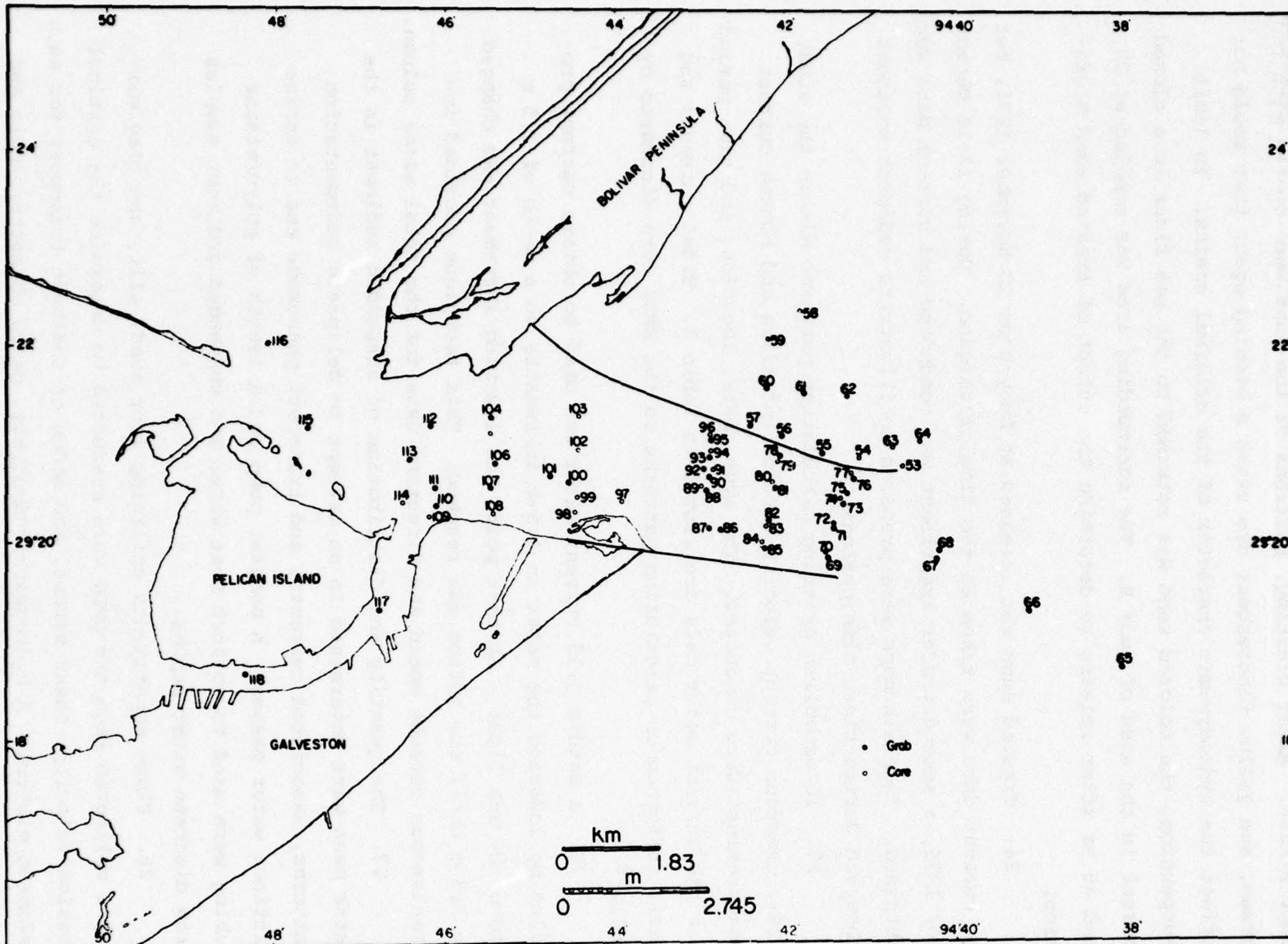


Figure 5. Location of bottom sediment samples taken near the Galveston Jetties; predisposal survey

sentative of the local sediments, 545 kg of sand were collected at the buoy B site. After cleaning, portions of the sand were coated with red, green, and yellow fluorescent dye using a binding agent that would not affect the hydrodynamic character of the original grains. To limit suspension, the colored sand was returned to the sea floor in a closed vessel in the area of buoy B. The surrounding area was sampled at 24 and 48 hr after release to determine the extent of treated sand migration.

24. Treated sand was released at buoy B on 10 November 1975, but no current data were taken at the time of release. During 12-14 December 1975, a second tracer experiment was conducted and current data were obtained. Isopleth maps were prepared to illustrate sediment movement observed during these time periods.

25. To establish existing circulation patterns within the study area, numerous current velocity vertical profiles and bottom current measurements were conducted. The type, date, location, and time period for the current meter data are listed in Table 1. Tidal currents and their influence on circulation patterns in the DMDS were discussed by Hall.[19]

26. A Bendix Q-15 current meter was used to obtain current profiles by lowering the meter in 1.5-m increments to a depth of 1.5 m above the sea floor. At this point the lowering increment was changed to 0.3 m until the bottom was reached. This technique provided instantaneous current speed and direction data for the total water column.

27. The quantity and distribution of suspended sediment in the water mass were determined in an attempt to delineate sedimentation patterns, associated currents, and transport phenomena and to define distinct water masses. A booster pump and a length of polyurethane tubing were used to collect most water and suspended sediment samples from discrete water depths.

28. Flume experiments utilizing four sand, silt, and clay mixtures collected from the DMDS were conducted to determine the critical erosion velocity, shear stress, and modes of sediment transport for each sediment mixture. A hydrographic analysis, based on meteorologic and

oceanographic data collected between February and June 1976 for the offshore Galveston area, was also performed. Results of the flume experiments and the hydrographic analysis were extrapolated to sediment transport processes believed operative in the DMDS.

29. Flume experiment samples were taken with a 0.3-m^3 box corer, which allowed recovery of approximately 100 kg from each of the four sampling locations within the DMDS. Samples were obtained from block 15 and buoy C sites (block 12) during November 1975; block 27 and buoy D sites were sampled in May 1976. Sample locations for blocks 15 and 27 were determined using time-velocity runs from marked locations and are therefore approximate. Buoys C and D sampling site stations were located approximately 30 m southwest of the respective buoys, which permitted the sampling of disposed dredged materials. In addition to the inertia current meters, current data were also collected with a Bendix Q-15 current meter and two Braincon Savonius continuous recording current meters from buoy sites B and D.

30. Grain-size analyses were performed on homogenized field samples utilizing the sieve and pipette methods of Folk;[17] statistical parameters of mean, standard deviation, skewness, and kurtosis were also determined. The physical properties of collected samples were determined and critical shear stress and erosional velocity were determined by flume experiments.

31. A final facet of the study involved the use of remote sensing of dredged material disposal operations. Overflights were made on 28 August, 9-10 September, and 9 October 1975. Overlapping photos were taken along a prearranged flightline using Eastman Kodak Ektachrome infrared film with a Wratten 15 (yellow) filter. For sake of brevity, these photos are not included in this report; selected photos are reproduced in Bouma and Huebner.[20]

32. During the final study phase (postdisposal) from January through June 1976, bathymetric, sedimentologic, and hydrologic data were collected within and adjacent to the DMDS. Figure 6 illustrates the sampling pattern employed during each of the three (January, March, and May) sampling periods. During these periods, five separate spade core

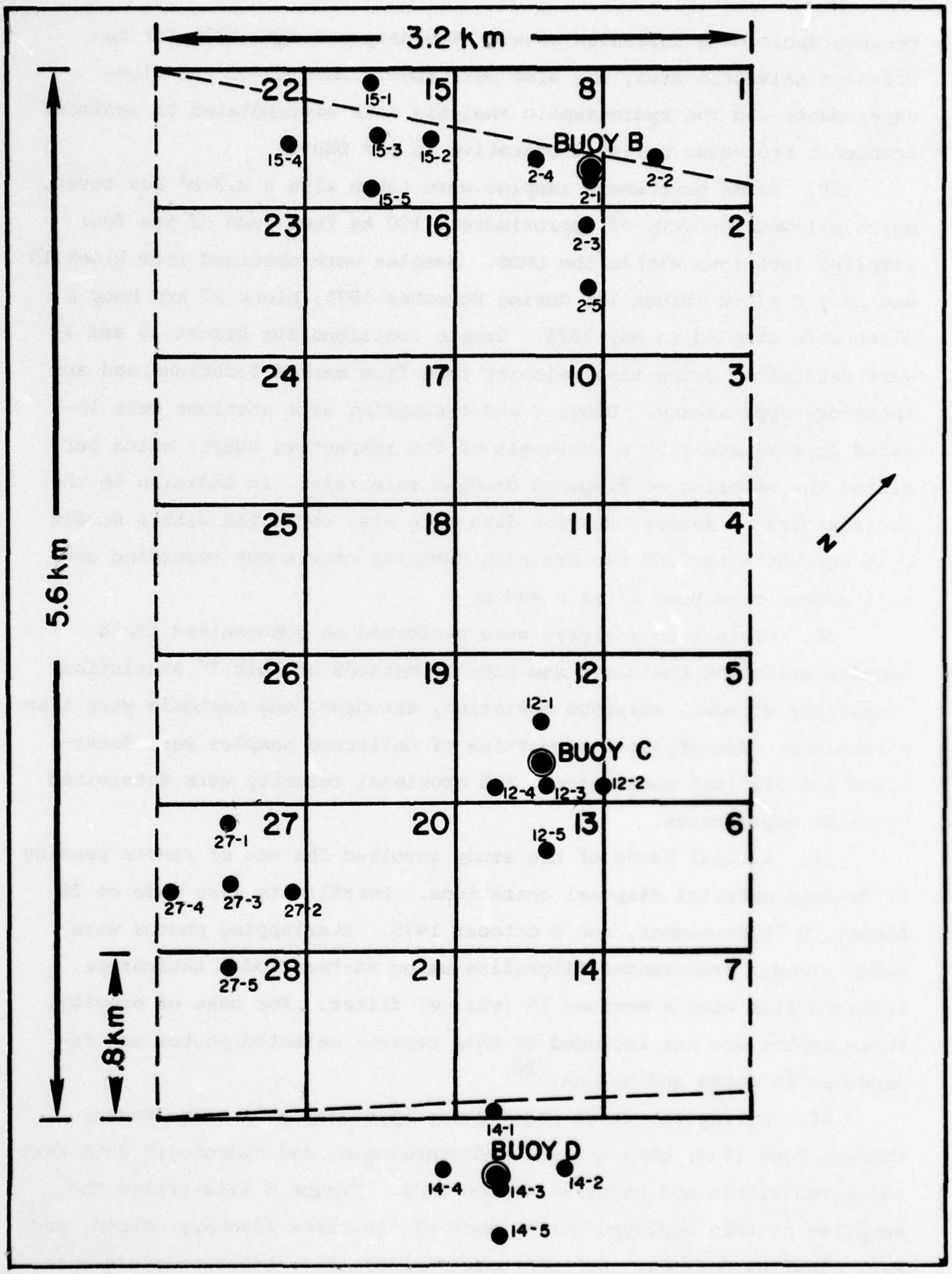


Figure 6. Station locations in areas 8, 12, 14, 15, and 27; DMDS post-disposal study

samples were collected from each ship station while the vessel was anchored. These samples, designated A through E, were utilized for both geological and biological analysis. A 2.54-cm-diameter core tube was used to collect a sediment subsample from each spade core sample. Sediment analyses were performed on replicates A, C, and E. Subsample D was used for carbonate determinations; subsample B was used for determination of combustible organic matter by heating dried samples to 600°C for two hr and determining weight loss.

33. Five sites (buoys B, C, and D and control sites 15 and 27) were sampled during each period. Accurate positioning of sampling locations was aided by use of buoys B, C, and D as reference points. Control sampling sites 15 and 27 were not subject to dredged material disposal; these areas were sampled as reference sites to assess the results of disposal in blocks 8 (buoy B), 12 (buoy C), and southeast of 14 (buoy D). Unfortunately, the lack of buoys in blocks 15 and 27 prevented accurate sample locationing. In addition, block 27 is not in the same textural province as the areas used for dredged material disposal, and as such, the results obtained from these areas are of little use in assessing changes in blocks 8, 12, and 14.

34. Bathymetric studies during the postdisposal sampling period were concentrated in the vicinity of the disposal sites at buoys B, C, and D. Dredged material isopach maps were prepared from the data obtained. Figures 7 through 9 illustrate the location of bathymetry profiles for buoy B, C, and D sites.

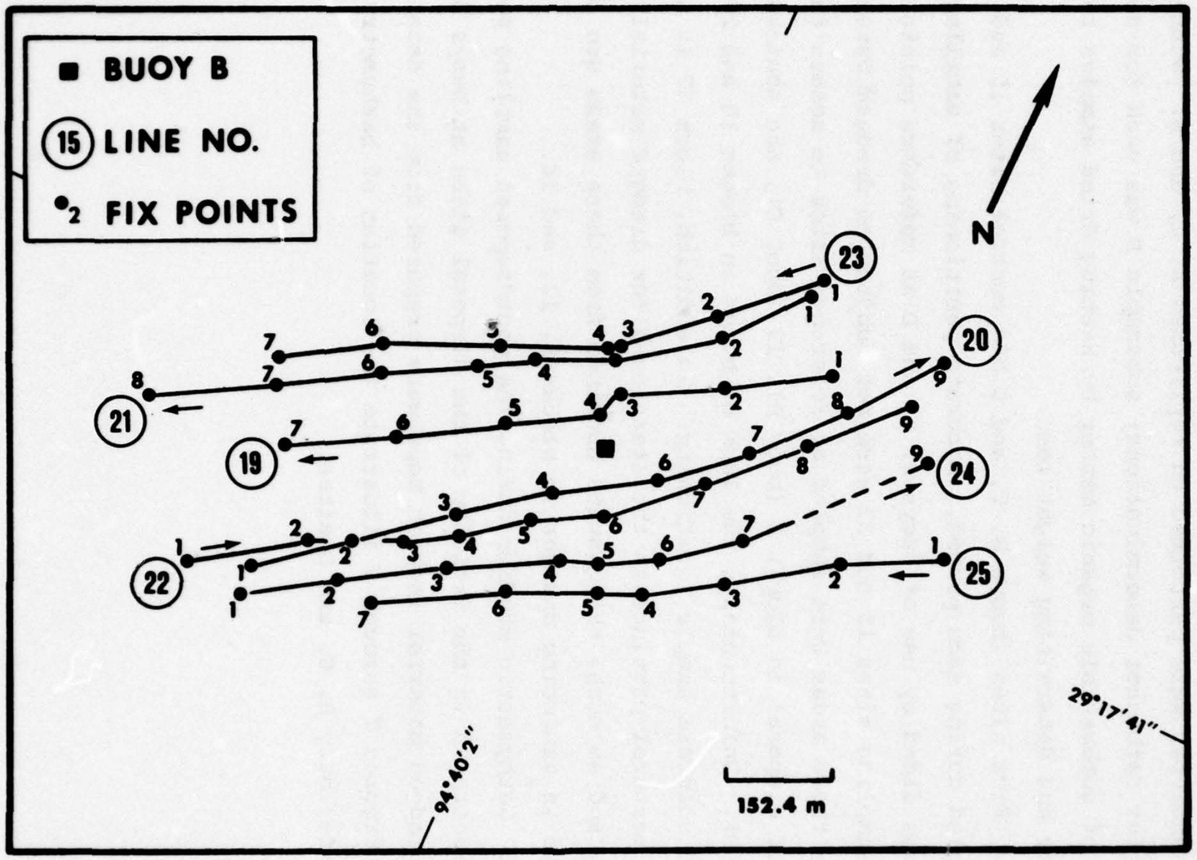


Figure 7. Bathymetric profile transects over mound B site, DMDS; postdisposal study

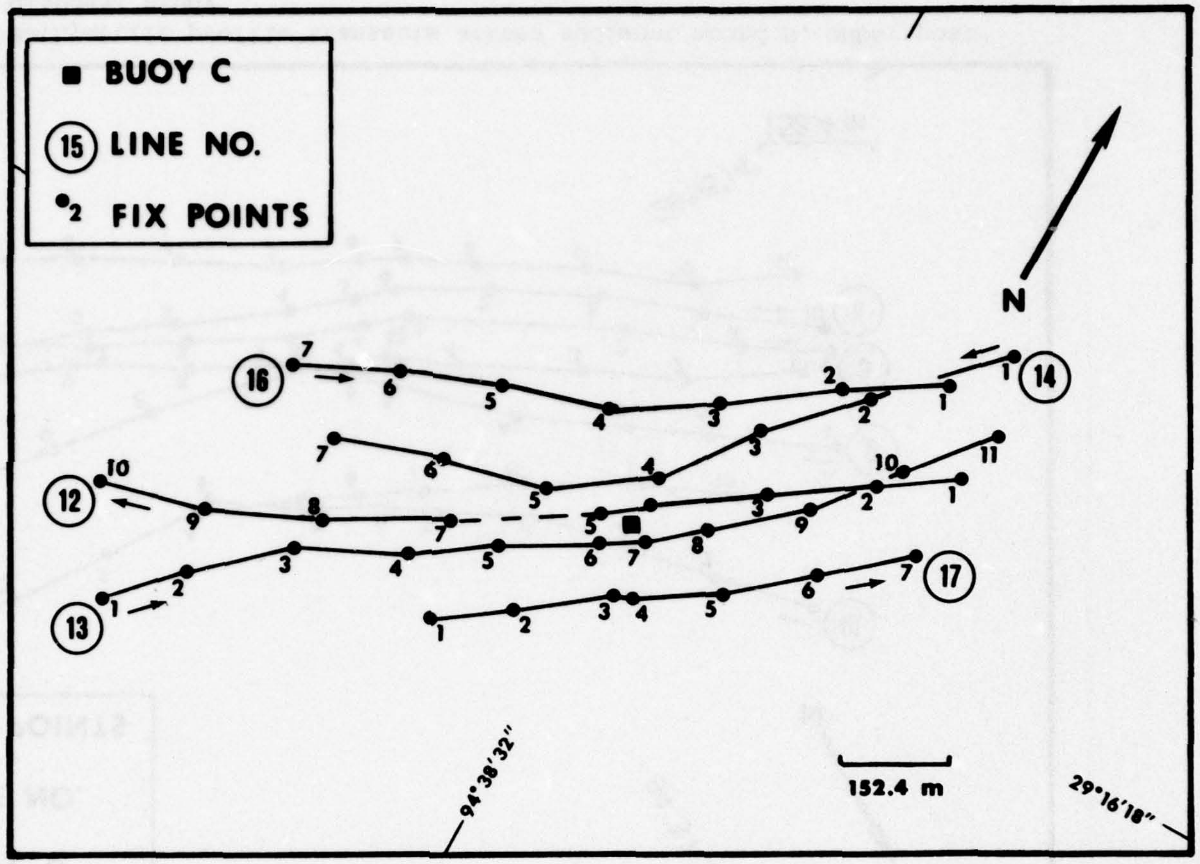


Figure 8. Bathymetric profile transects across sediment mound C, DMDS; post-disposal study

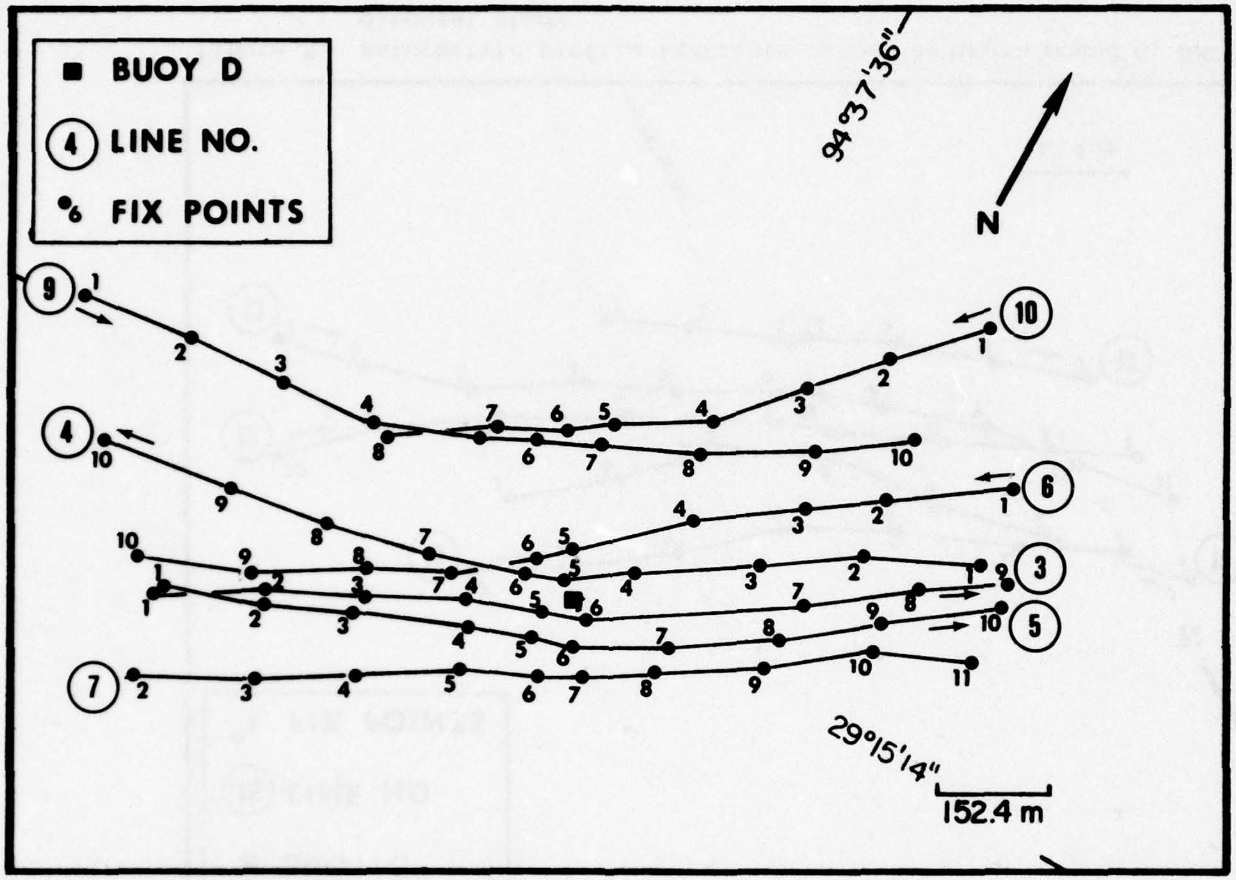


Figure 9. Bathymetric profile transects across sediment mound D, DMDS; post-disposal study

PART III: RESULTS

Bathymetry

35. Topographic changes of sea bottom mounds created by dredged material disposal may be directly determined by comparing pre- and post-disposal bottom contours. Approximately five months prior to dredged material disposal operations, a baseline bathymetric survey was conducted in the DMDS to document the nature of the bottom topography. Figure 10 depicts the bathymetry of the DMDS and illustrates that the initial bathymetry of the disposal area was generally smooth, sloping about 0.9 m/km toward the southeast, normal to the coast.

36. Side scan sonar records of the area detected several shallow, long, straight depressions, which were interpreted as anchor drag furrows. To the northeast of the DMDS, the gently sloping topography was broken by a mound about 1.2 m high, which covered about 2 km^2. Another smaller topographic high was also identified to the northwest of the DMDS. This high was about 0.6 m above the surrounding bottom and covered approximately 0.4 km^2. The northeastern topographic high is believed to represent a dredged material disposal site; no explanation was given for the northwestern high.[21] It should be noted that the areal extents of each of the above-described topographic highs are crude estimates; only general surface area determinations were possible from available data.

37. Immediately after completion of the dredging and dredged material disposal operations, a second survey was conducted to define the morphology of the mounds created by disposal operations (Figure 11). Subsequent bathymetric surveys were conducted in November and December to ascertain if any changes occurred in the mounds due to hydraulic forces operating at each site. The results of the bathymetric surveys conducted at the disposal sites during November and December were not considered valid because the microwave navigation system was inoperative; navigation was conducted by dead reckoning. An additional bathymetric survey utilizing the microwave system was performed on 21 June

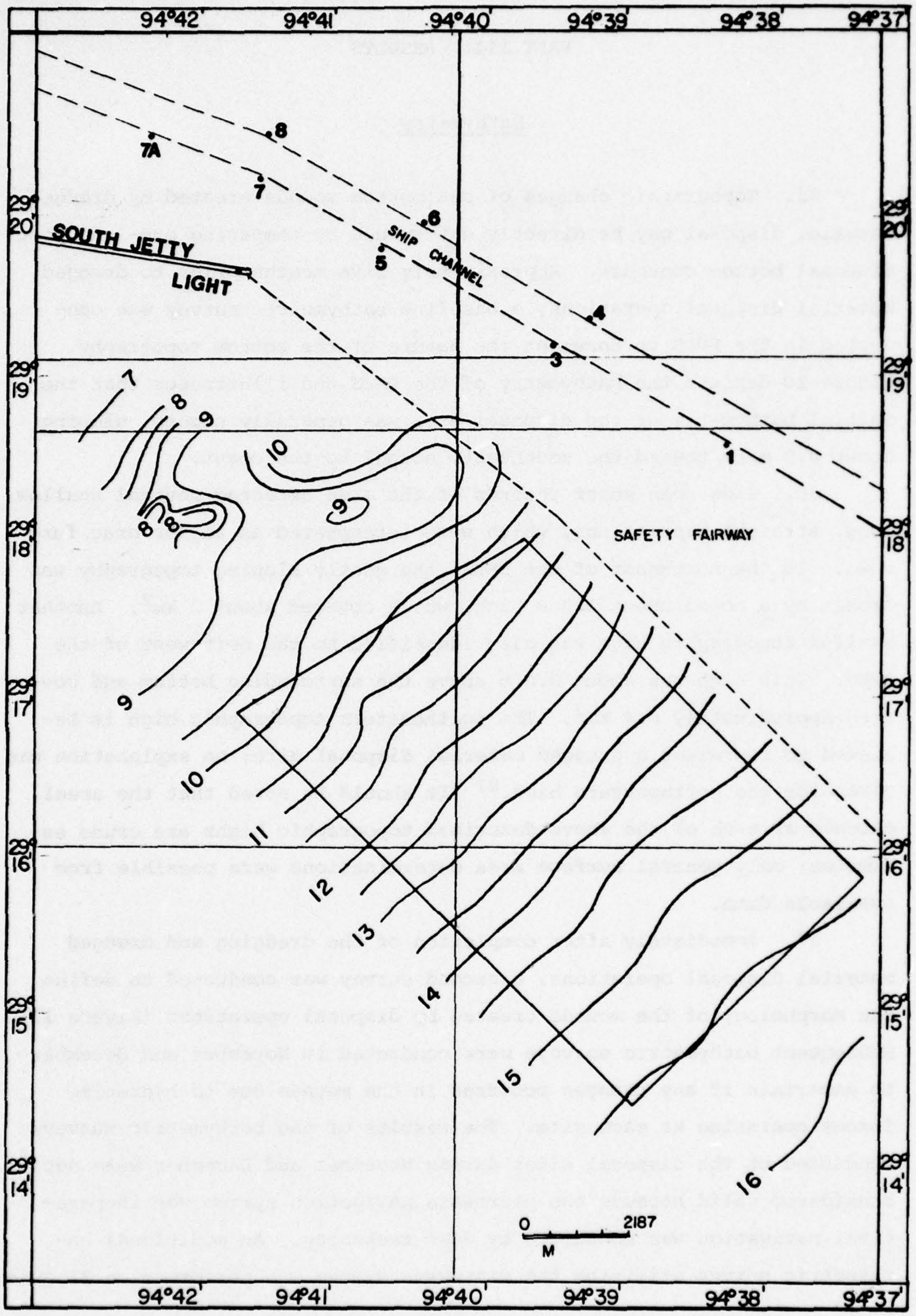


Figure 10. Predisposal bathymetry of the DMDS; March 1975

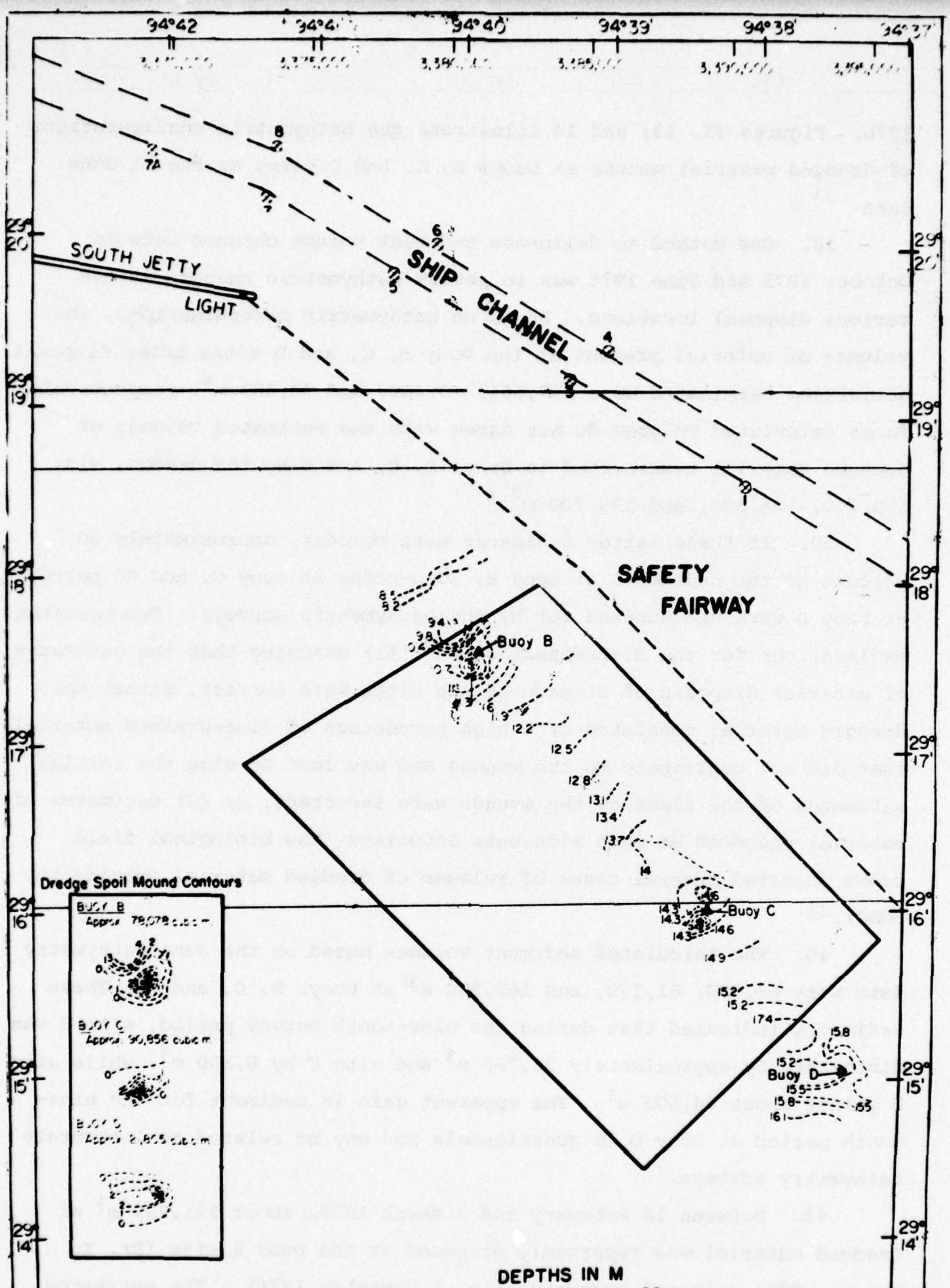


Figure 11. Postdisposal bathymetry of specific disposal sites, DMDS; September 27, 1975

1976. Figures 12, 13, and 14 illustrate the bathymetric configurations of dredged material mounds at buoys B, C, and D based on the 21 June data.

38. One method to delineate sediment volume changes between October 1975 and June 1976 was to review bathymetric changes at the various disposal locations. Based on bathymetric determinations, the volumes of material present at the bouy B, C, and D sites after disposal activities terminated were 137,664, 69,468, and 98,683 m^3, respectively. These calculated volumes do not agree with the estimated volumes of dredged material transported to buoys B, C, and D by the dredge, viz: 190,700, 105,500, and 195,700 m^3.[1]

39. If these latter estimates were correct, approximately 30 percent of the sediments at buoy B, 33 percent at buoy C, and 50 percent at buoy D were unaccounted for by the bathymetric surveys. Two possible explanations for the discrepancies are: (1) assuming that the estimates of material disposed of at each of the sites were correct, either the dredged material consisted of a high percentage of fine-grained material that did not contribute to the mounds and was lost or else the initial estimates of the sizes of the mounds were incorrect; or (2) estimates of material disposed at each site were incorrect (the biological field crews observed several cases of release of dredged material outside the DMDS).[22]

40. The calculated sediment volumes based on the June bathymetry data were 64,900, 61,170, and 163,200 m^3 at buoys B, C, and D. These estimates indicated that during the nine-month survey period, site B was diminished by approximately 72,760 m^3 and site C by 8,300 m^3, while site D gained about 64,500 m^3. The apparent gain in sediment for the nine-month period at buoy D is questionable and may be related to inaccurate bathymetry surveys.

41. Between 18 February and 3 March 1976, about 211,220 m^3 of dredged material was reportedly disposed at the buoy B site (Dr. T. Wright, EEL, personal communication, 5 November 1976). The estimated total amount of dredged material disposed at site B was, therefore, 401,920 m^3; but only 64,900 m^3 was accounted for by the June 1976

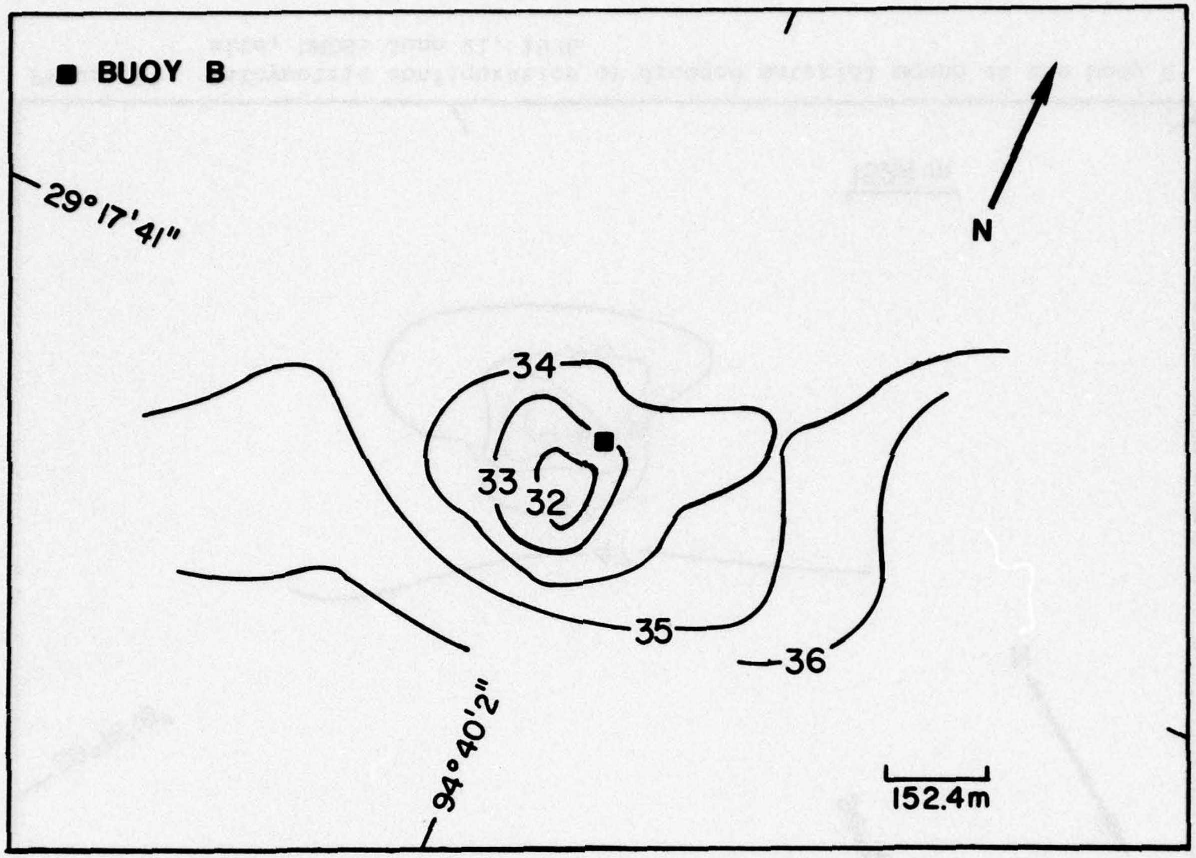


Figure 12. Bathymetric configuration of dredged material mound at the buoy B site, DMDS; June 21, 1976

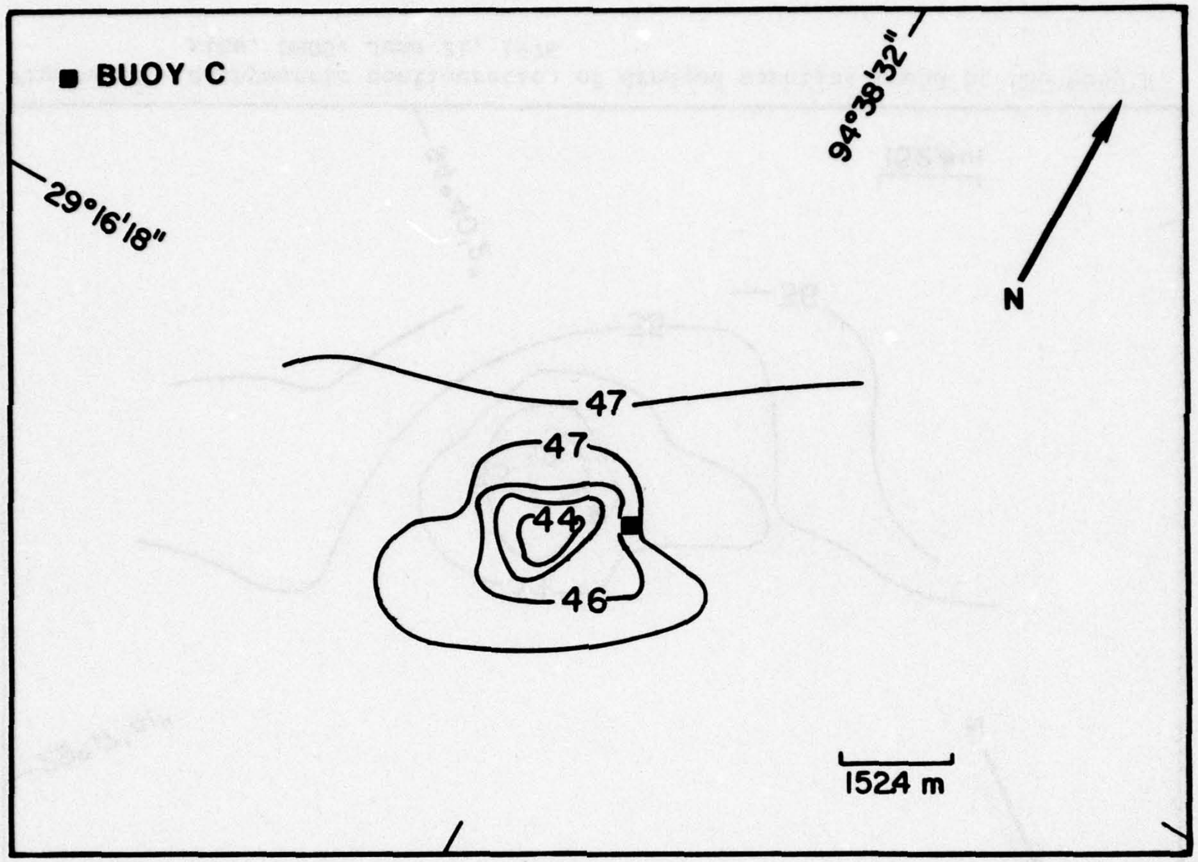


Figure 13. Bathymetric configuration of dredged material mound at the buoy C site, DMDS; June 21, 1976

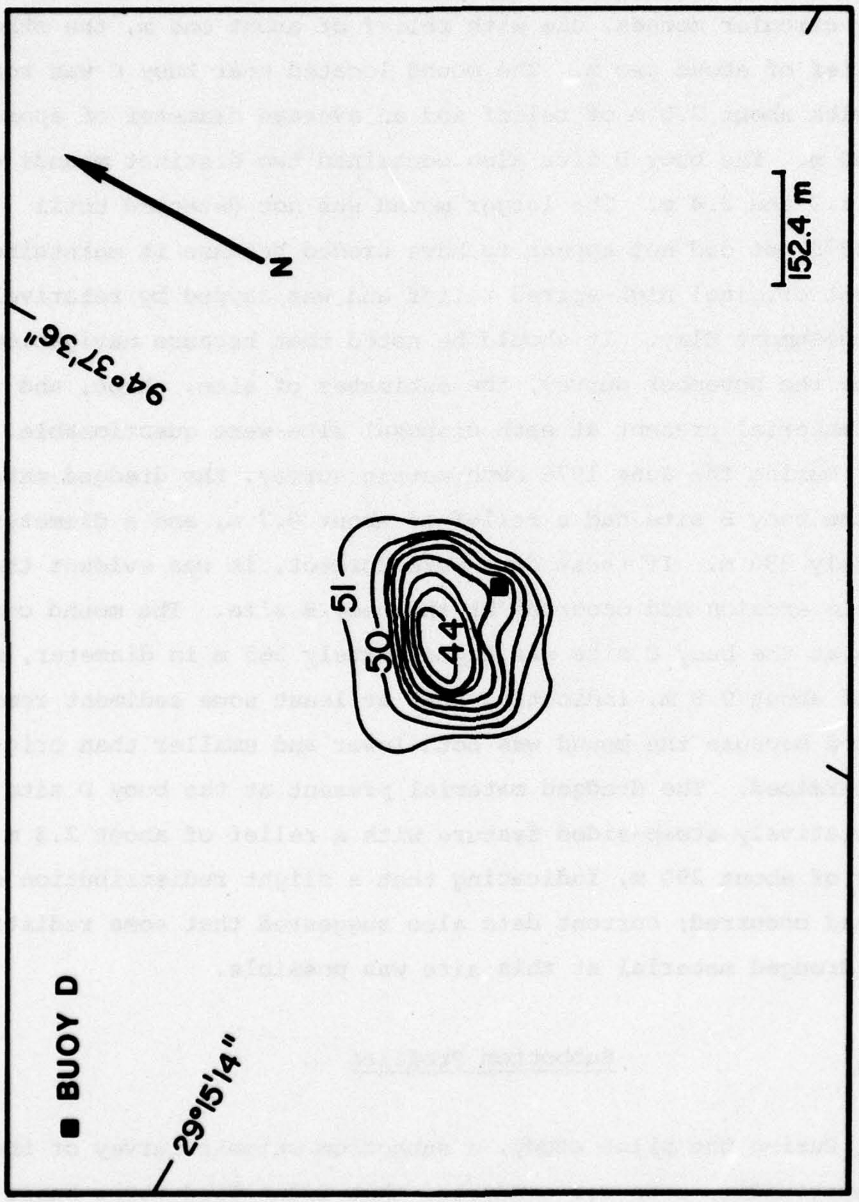


Figure 14. Bathymetric configuration of dredged material mound at the buoy D site, DMDS; June 21, 1976

bathymetric survey. This amounted to an apparent loss of about 337,000 m^3.

42. A second approach to determine loss of sediment from disposal mounds was to compare changes in mound configuration through time. During the September 1975 survey, buoy B site dredged materials formed two nearly circular mounds, one with relief of about one m, the other with a relief of about two m. The mound located near buoy C was roughly circular with about 2.0 m of relief and an average diameter of approximately 460 m. The buoy D site also contained two distinct mounds with relief of 1.3 and 2.4 m. The larger mound was not detected until November 1975 but did not appear to have eroded because it maintained its apparent original high-spired relief and was capped by relatively resistant Beaumont Clay. It should be noted that because navigation was poor during the November survey, the estimates of size, shape, and volume of material present at each disposal site were questionable.

43. During the June 1976 bathymetric survey, the dredged material mound at the buoy B site had a relief of about 0.7 m, and a diameter of approximately 380 m. If these data were correct, it was evident that considerable erosion had occurred at the buoy B site. The mound configuration at the buoy C site was approximately 365 m in diameter, with a relief of about 0.8 m, indicating that at least some sediment removal had occurred because the mound was both lower and smaller than originally determined. The dredged material present at the buoy D site was still a relatively steep-sided feature with a relief of about 2.3 m and a diameter of about 290 m, indicating that a slight redistribution of material had occurred; current data also suggested that some redistribution of dredged material at this site was possible.

Subbottom Profiles

44. During the pilot study, a subbottom seismic survey of the DMDS and surrounding area was conducted that identified three basic horizons. Two lower reflectors, 'A' and 'B', were interpreted as lag concentrations of sandy materials believed representing storm deposits

(Figures 15 and 16). The shallowest reflector, 'C', lies about 7.3 to 8.2 m below the sea bottom (Figure 17).

45. The relief and distribution of the three horizons have little bearing on the distribution of recently deposited sediments. The uppermost reflector, 'C', is about 7.5 m below the modern sea floor within the DMDS. Reflectors 'A', 'B', and 'C' will therefore not be discussed in any subsequent sections since they have no direct bearing on the distribution and/or redistribution of disposed dredged materials within the DMDS.

Sediment Distribution

Pilot study

46. Twenty-eight sediment samples were collected during the pilot study. These sediment data are listed in Table 2 and the mean grain-size distribution is shown in Figure 18. The sediments in the DMDS were primarily silt and clay with up to 30-50 percent sand, except in the north corner (blocks 1 and 8) where a tongue of fine sand (80-90 percent sand) was identified.

Predisposal

47. The pilot study sediment distribution patterns do not agree with the predisposal sediment baseline data depicted in Figures 19 and 20.[21] The differences may be due to natural sedimentological changes that occurred through time or to differences in sampling locations. Pilot project samples were obtained during April and May 1975. The predisposal baseline samples were collected at a subsequent time and may be representative of the sediment distribution of the DMDS for that time period. The differences may also be due to different sampling techniques. Pilot project samples were subsampled from the spade corer. Predisposal study samples were obtained with a Van Veen grab sampler and a 136-kg gravity core. In addition, predisposal sample collections were not concentrated in the DMDS.

48. Sediment grain-size distribution maps were prepared from sediment data (Figures 19 and 21) and additional maps illustrating

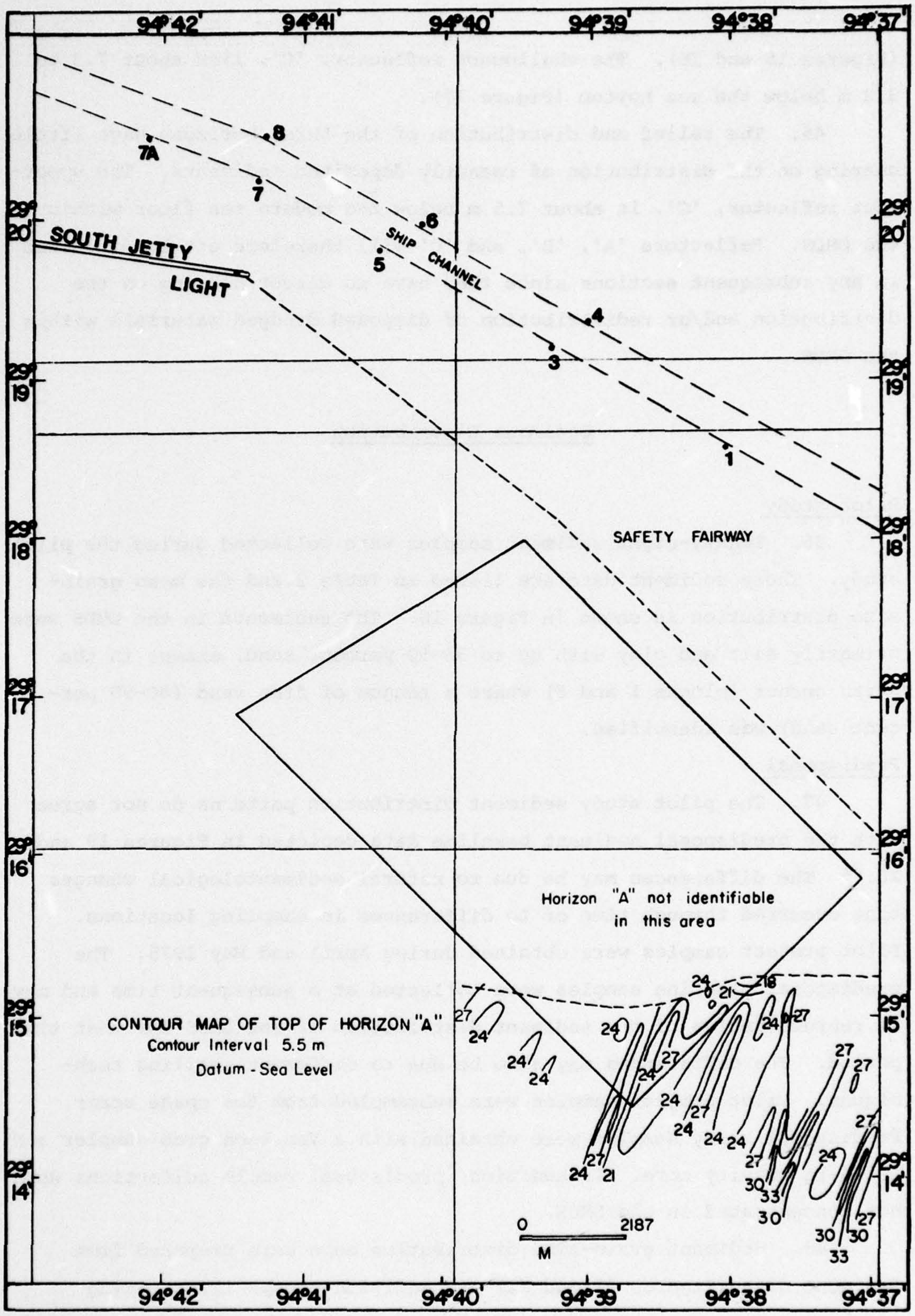


Figure 15. Contour map of the top of reflecting horizon 'A', DMDS

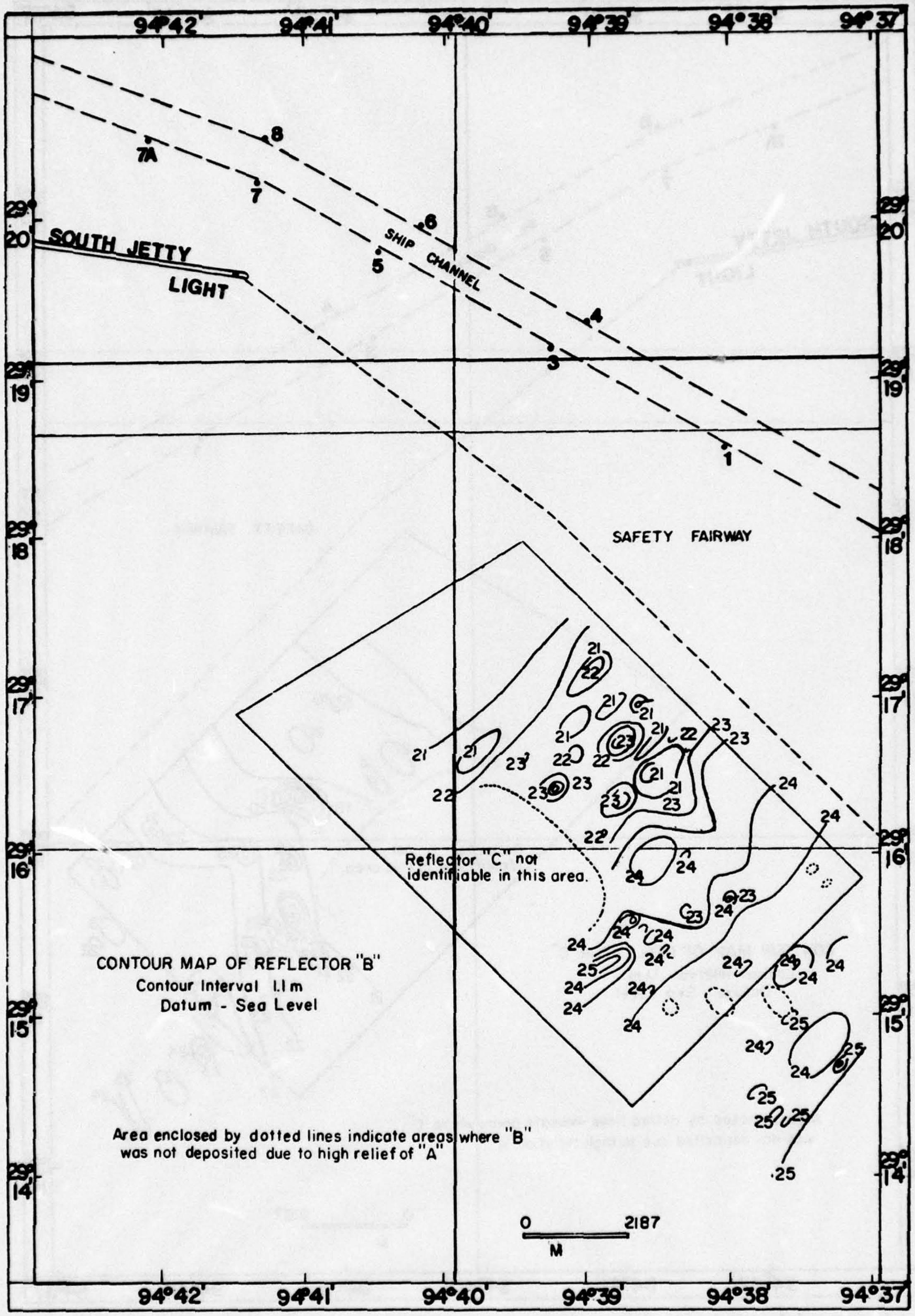


Figure 16. Contour map of the top of reflecting horizon 'B', DMDS

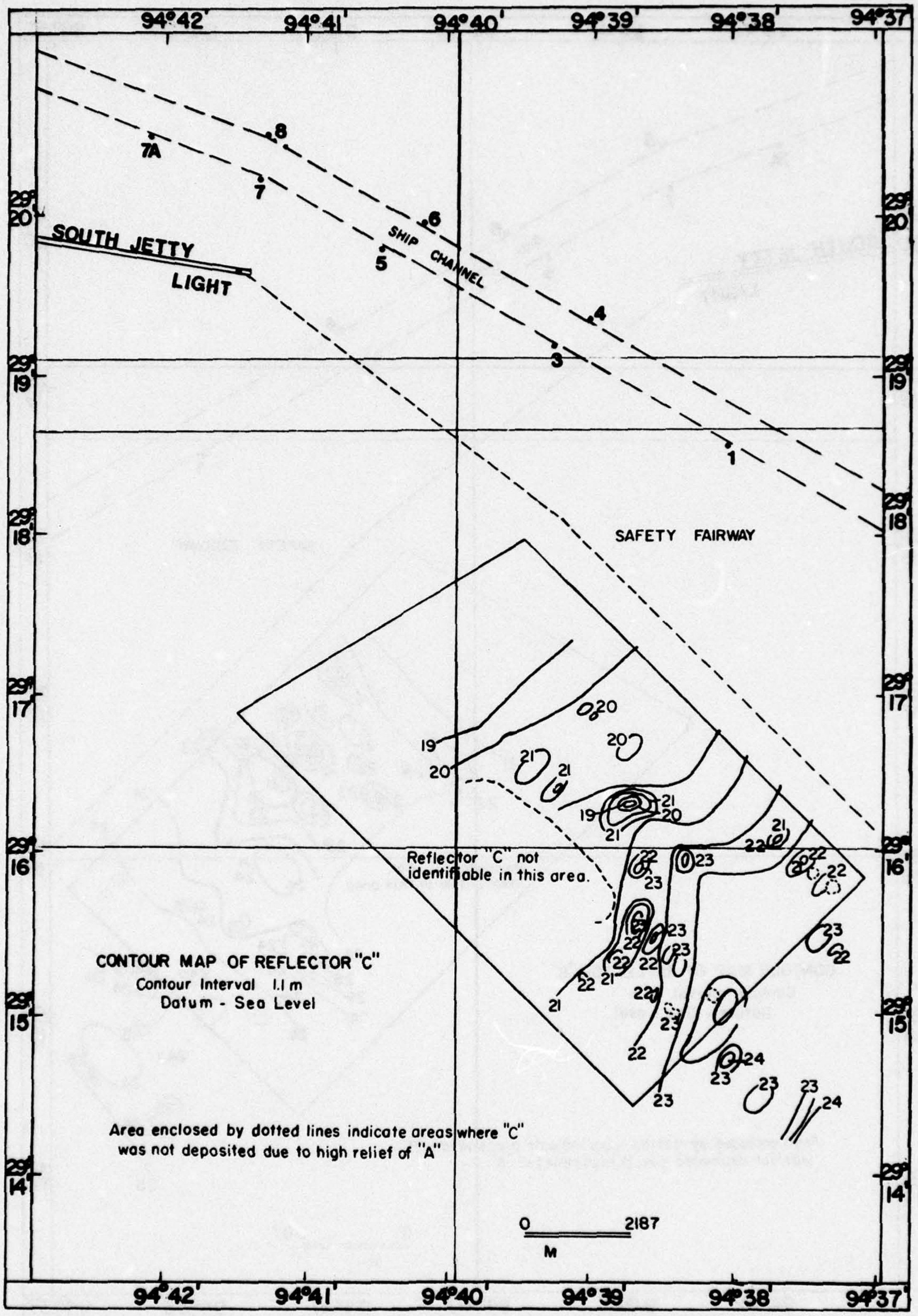


Figure 17. Contour map of the top of reflecting horizon 'C', DMDS

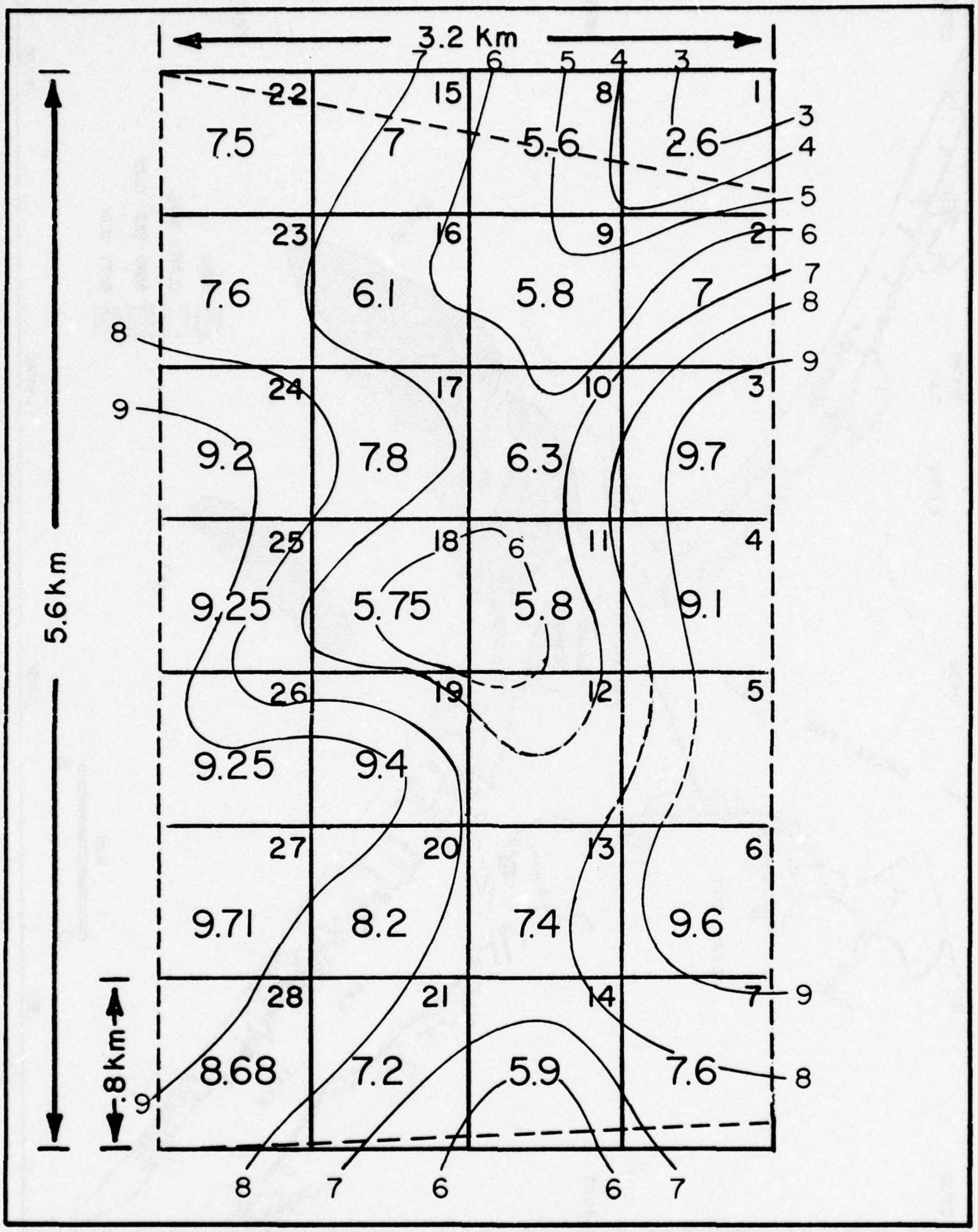


Figure 18. Mean grain-size distribution (Ø units), DMDS, pilot study

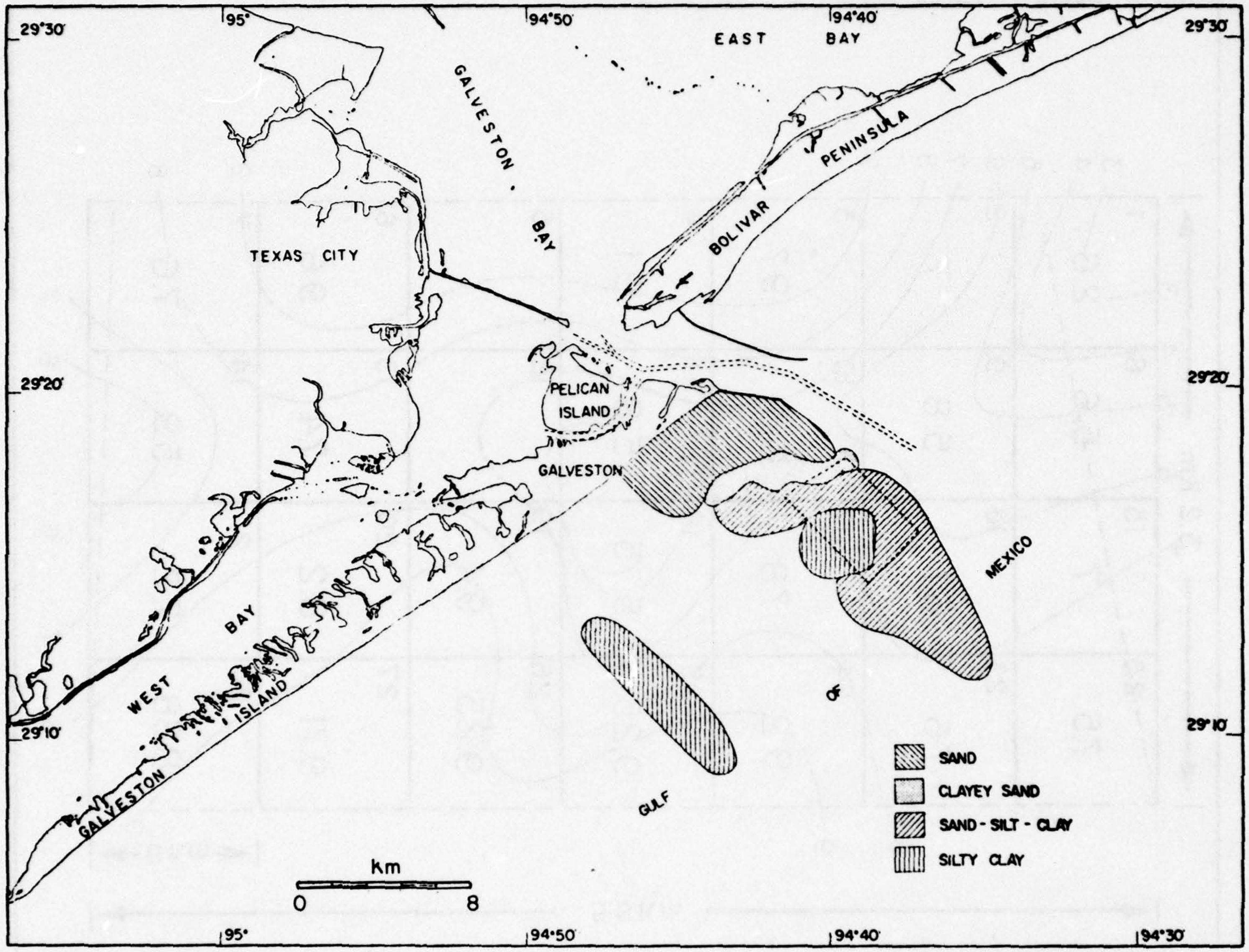


Figure 19. Sediment size distribution of offshore area, predisposal study

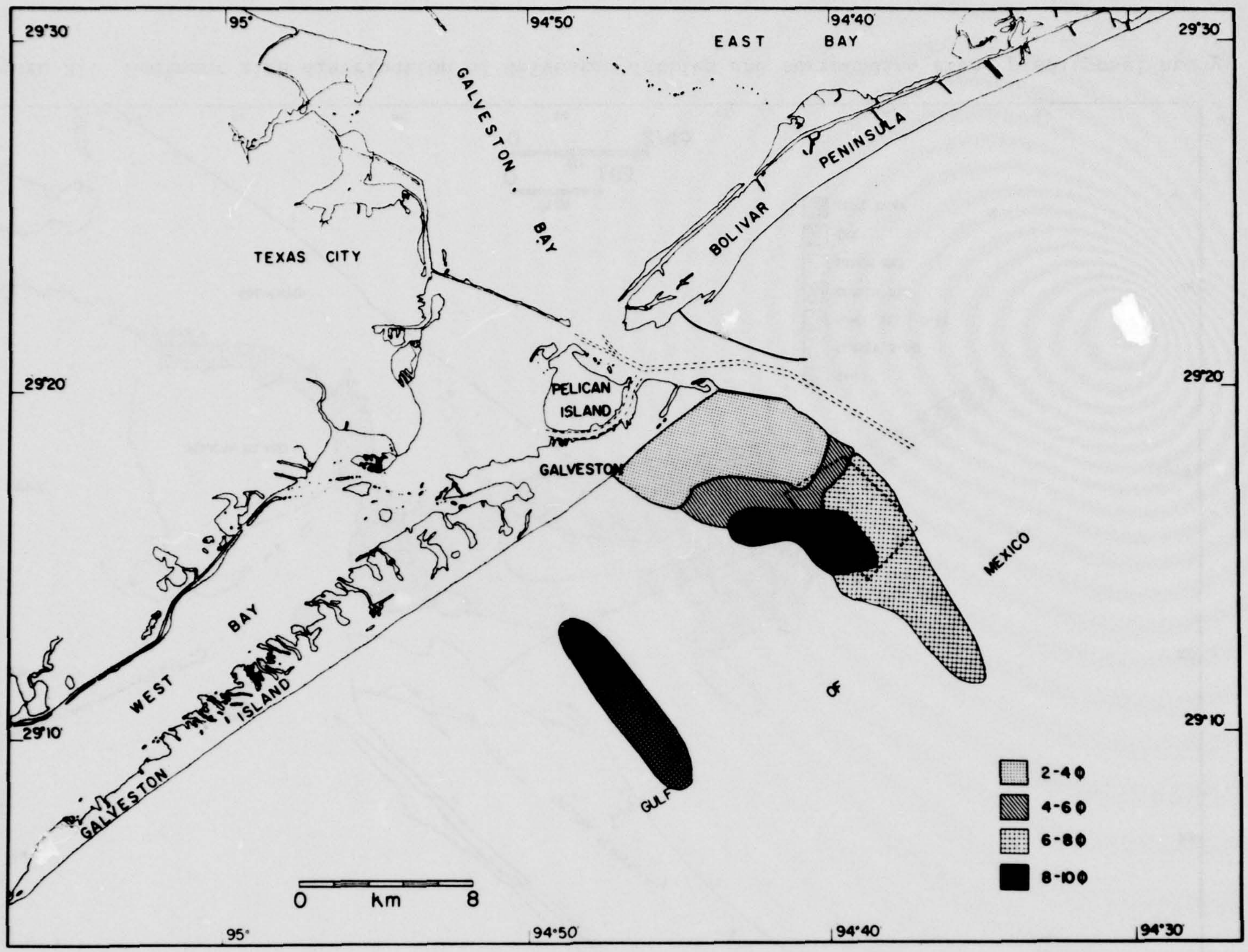


Figure 20. Graphic mean grain size of sediments, DMDS and surrounding area, predisposal study

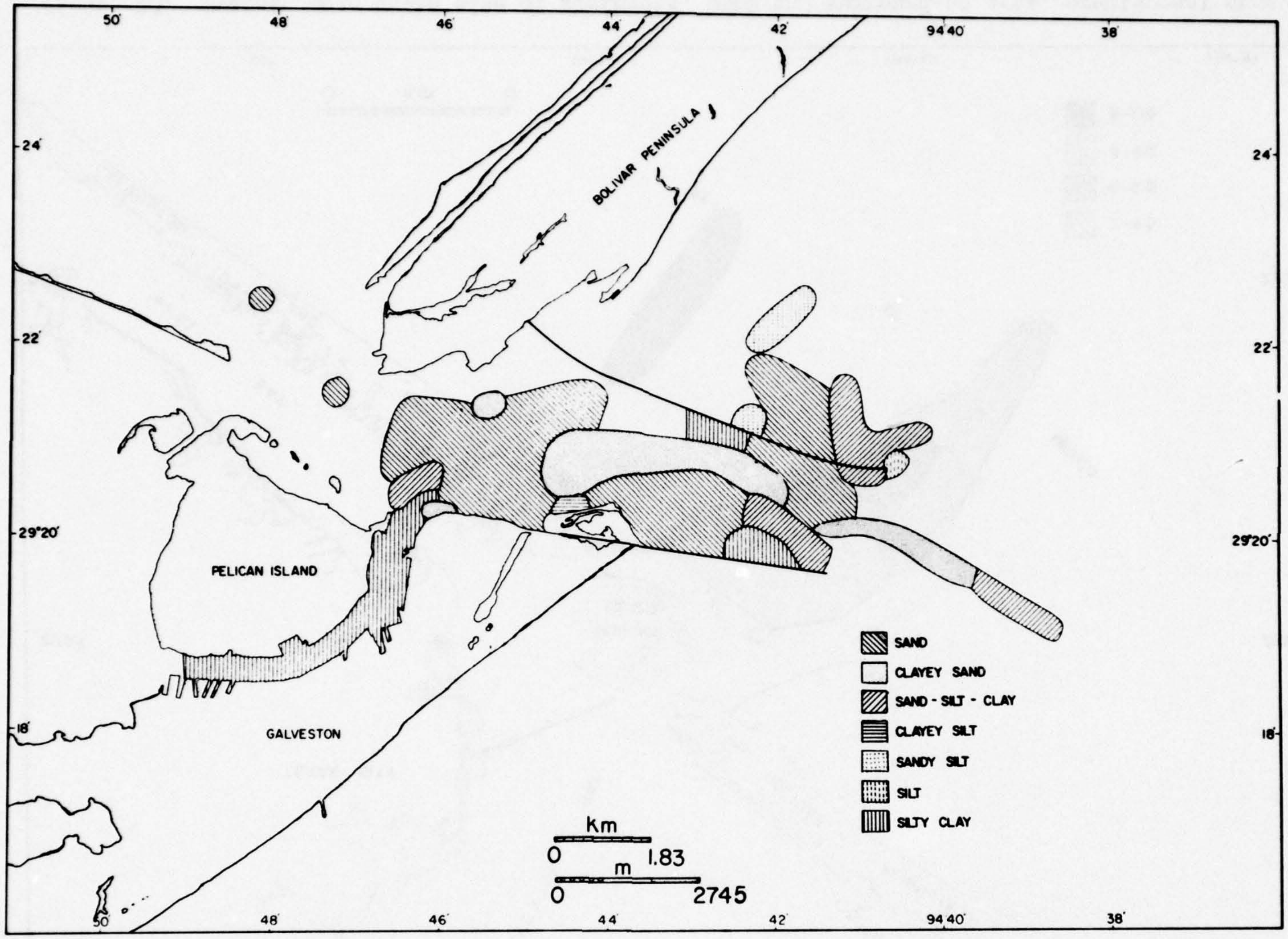


Figure 21. Sediment size distribution of Galveston Jetties and surrounding area, predisposal study

sample mean (Figures 20 and 22), median (Figures 23 and 24), standard deviation (sorting) (Figures 25 and 26), skewness (Figures 27 and 28), and kurtosis (Figures 29 and 30) were prepared from reduced data using the statistical methods of Folk.[17]

49. Few conclusions can be made about DMDS sediment distribution during the period June-September 1975 because predisposal sampling was concentrated outside the DMDS. Thus, only sedimentological changes that occurred from the pilot study phase to the postdisposal sampling phase of the project will be discussed.

Postdisposal

50. After disposal operations ceased on 24 September 1975, bottom sediments were sampled on a monthly basis at buoy sites B, C, and D and in reference blocks 15 and 27 from September through December. Both Van Veen and Petersen grab samplers were used at the various sampling locations during this four-month period. Accurate sampling locations for this period are not available for most samples and only broad generalizations can be made regarding changes in sediment composition.

51. A postdisposal sediment sample collected about 93 m west of buoy B on 26 September 1975 contained 82.1 percent sand, 4.6 percent silt, and 13.3 percent clay (Table 3). This sample differed from the pilot project sample taken at station 8 (buoy B site), which contained 71.2 percent sand, 7.8 percent silt, and 21.0 percent clay (Table 3). The October sample, taken about 19 m west of the buoy, differed from the September and pilot project samples from this area. This sample contained 69.1 percent sand, 10.9 percent silt, and 20.0 percent clay.

52. Duplicate November samples, taken near the buoy B disposal mound crest, contained 97.6 and 98.0 percent sand, suggesting that winnowing of silt- and clay-sized material had occurred. One sample taken at or near the disposal mound in December contained 63 percent sand-sized and coarser material; most of the sample consisted of carbonates. Generally, the sand content decreased from September and October to December. A review of Table 3 also illustrates that there was a high degree of

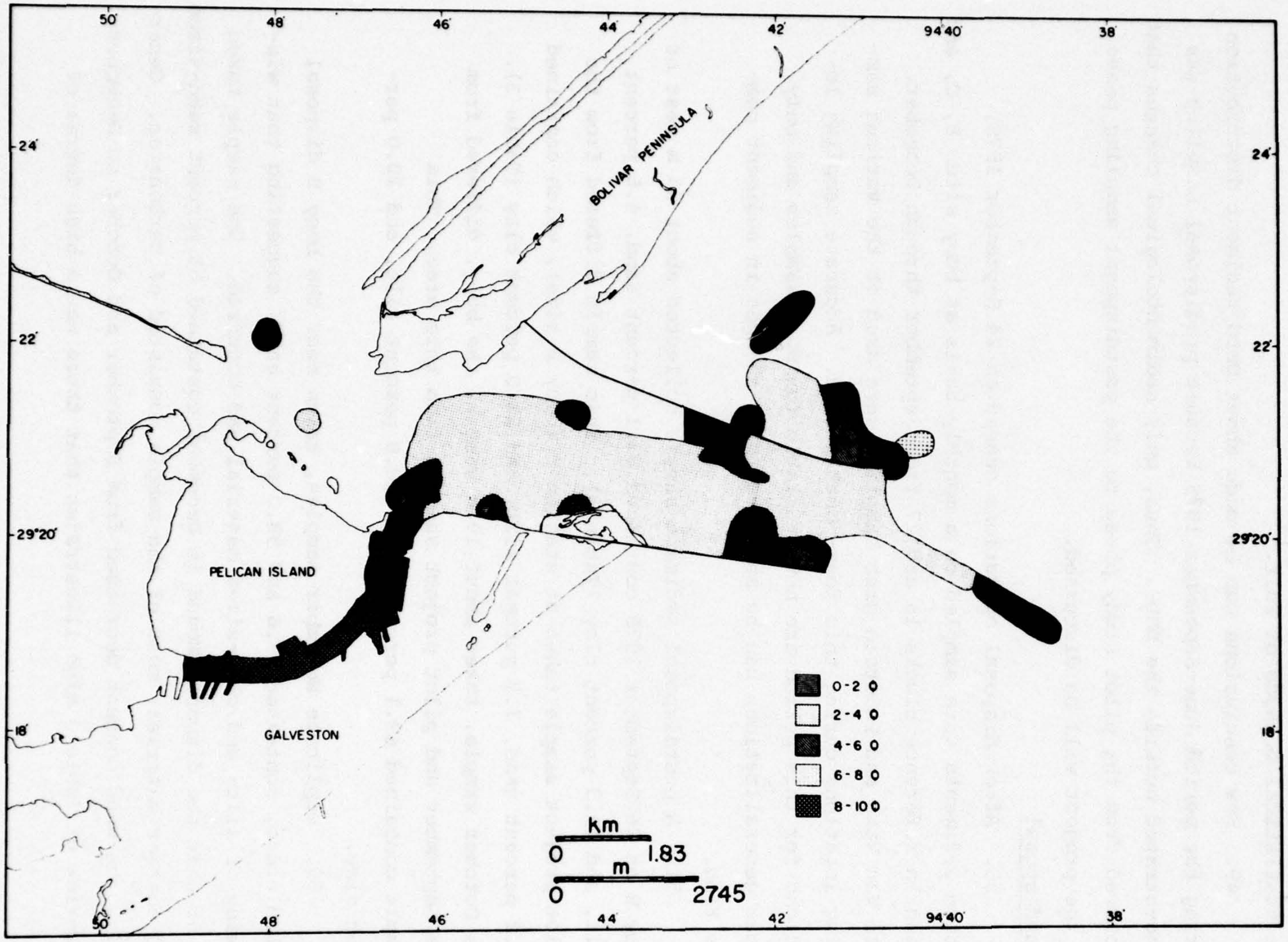


Figure 22. Graphic mean grain size of sediments; Galveston Jetties

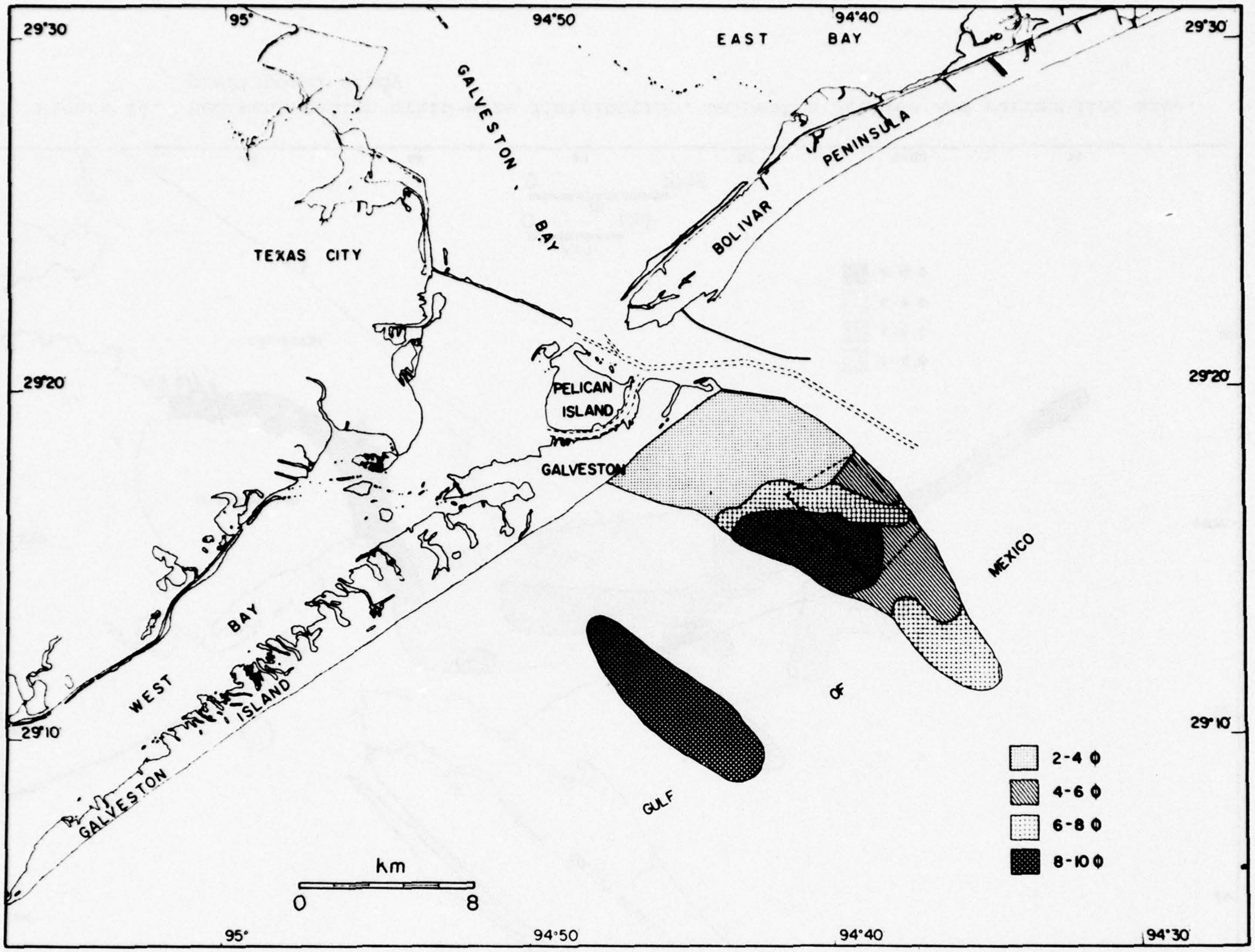


Figure 23. Sediment median grain-size distribution, DMDS and surrounding area, predisposal study

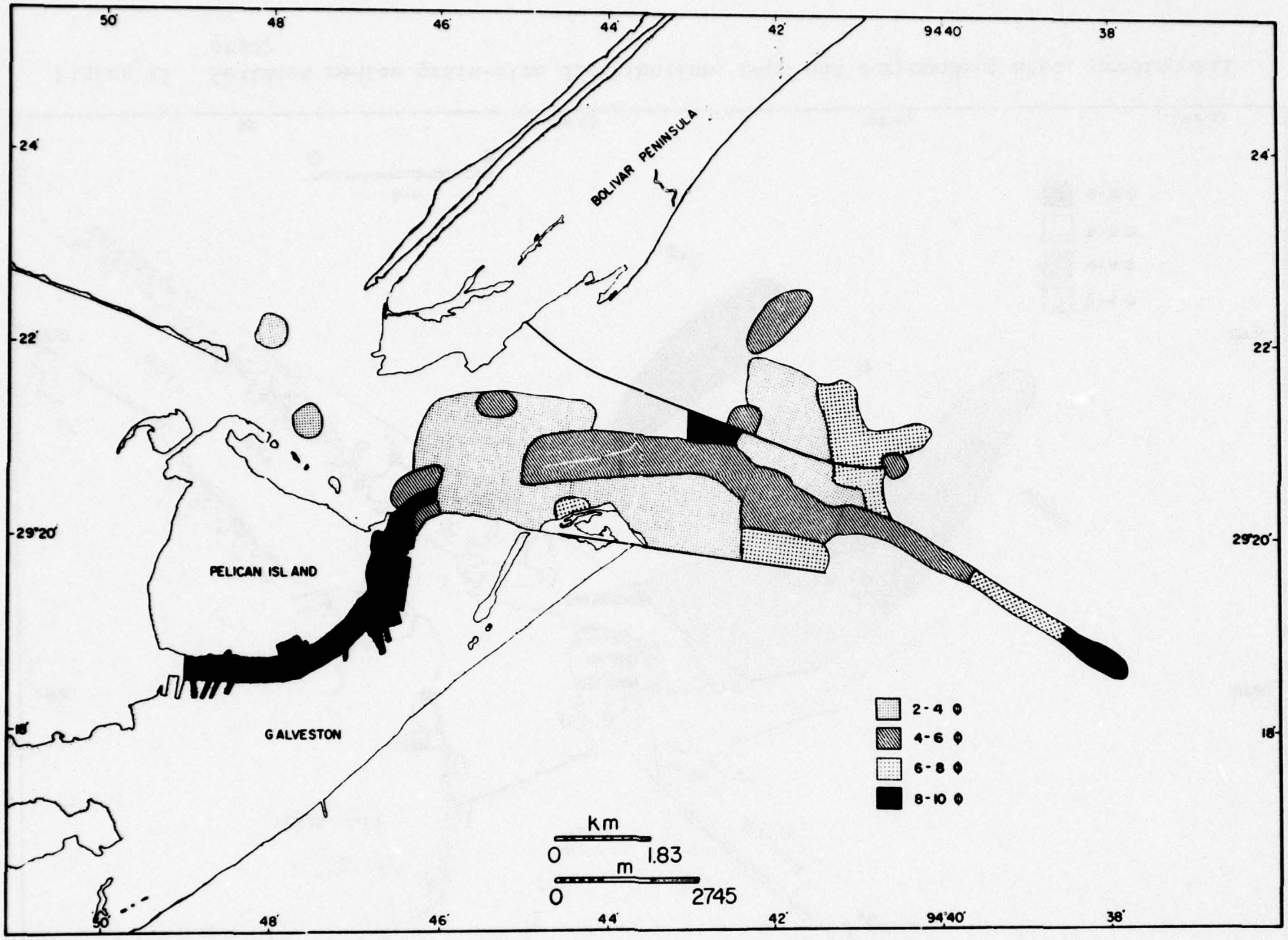


Figure 24. Sediment median grain-size distribution, Galveston Jetties and surrounding area, predisposal study

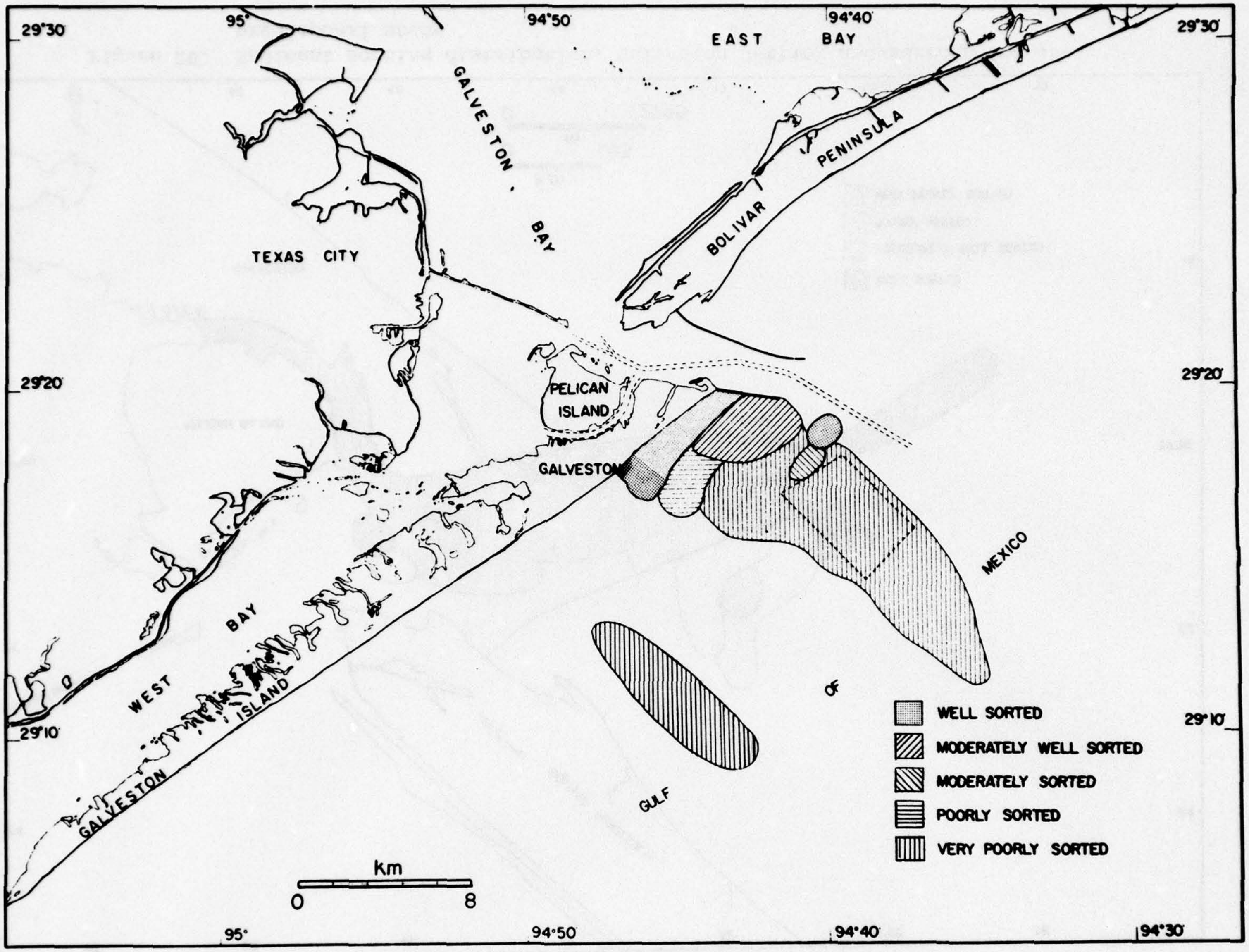


Figure 25. Sediment sorting distribution, DMDS and surrounding area, predisposal study

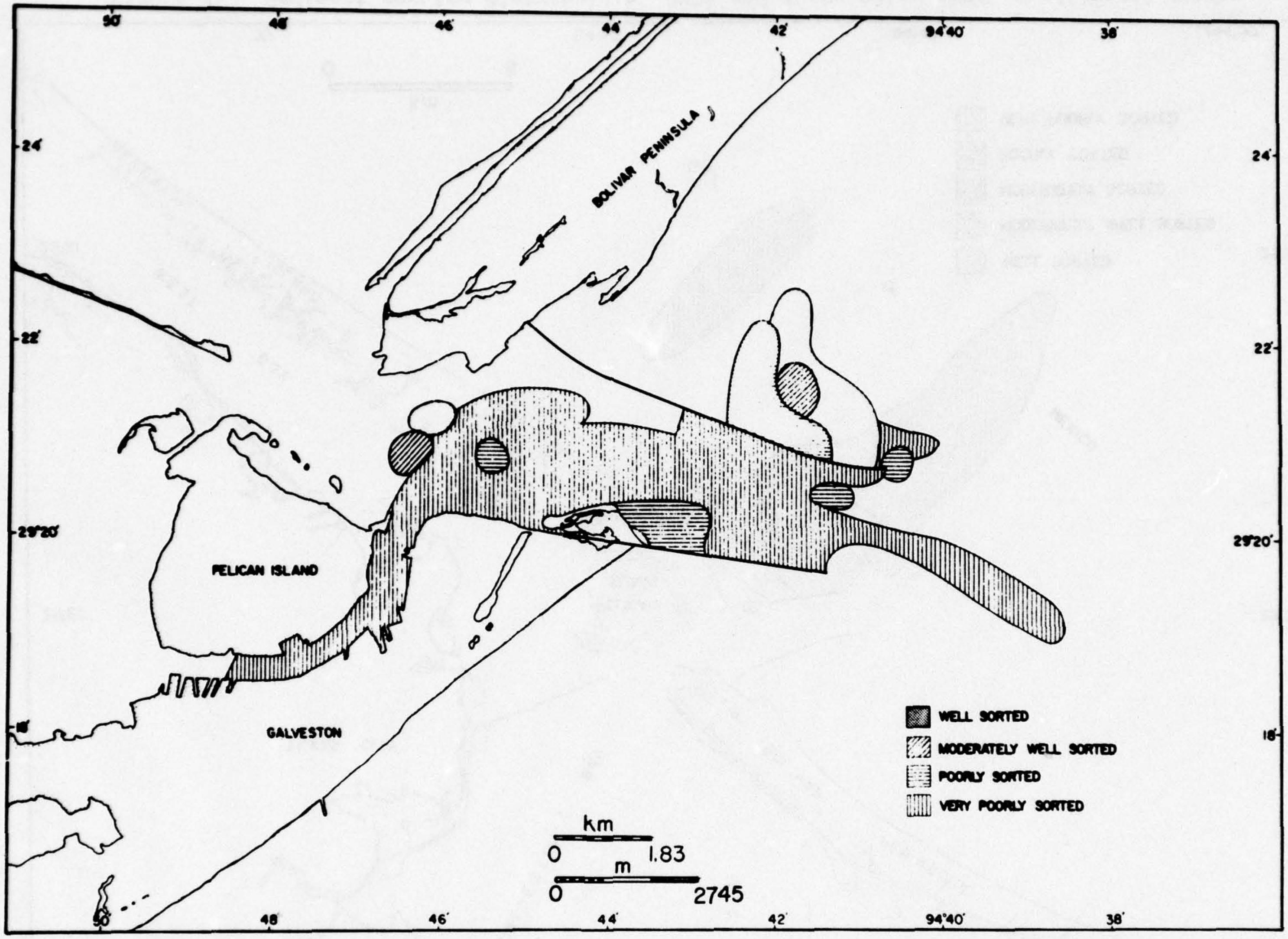


Figure 26. Sediment sorting distribution, Calveston Jetties and surrounding area, predisposal study

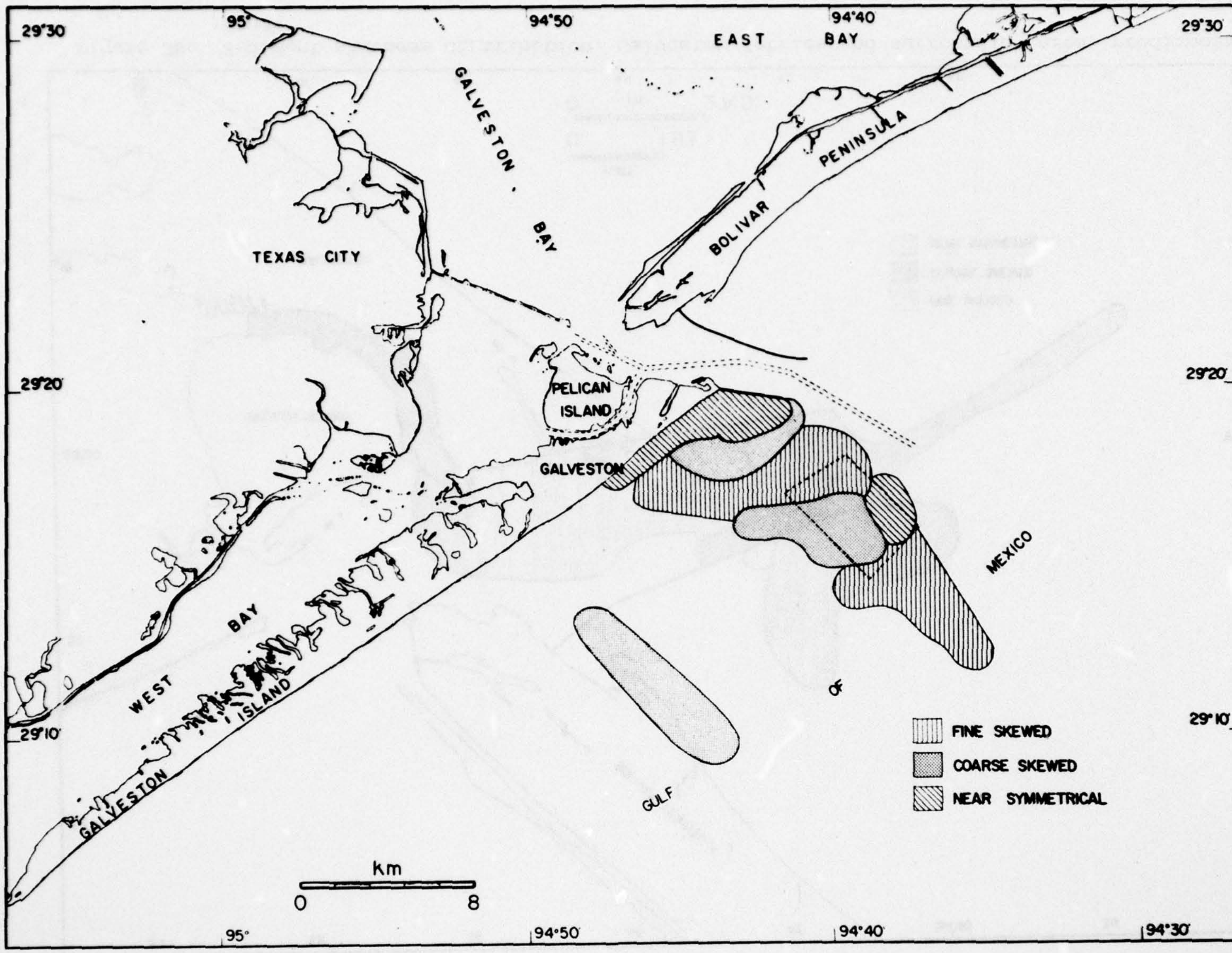


Figure 27. Sediment skewness distribution, DMDS and surrounding area, predisposal study

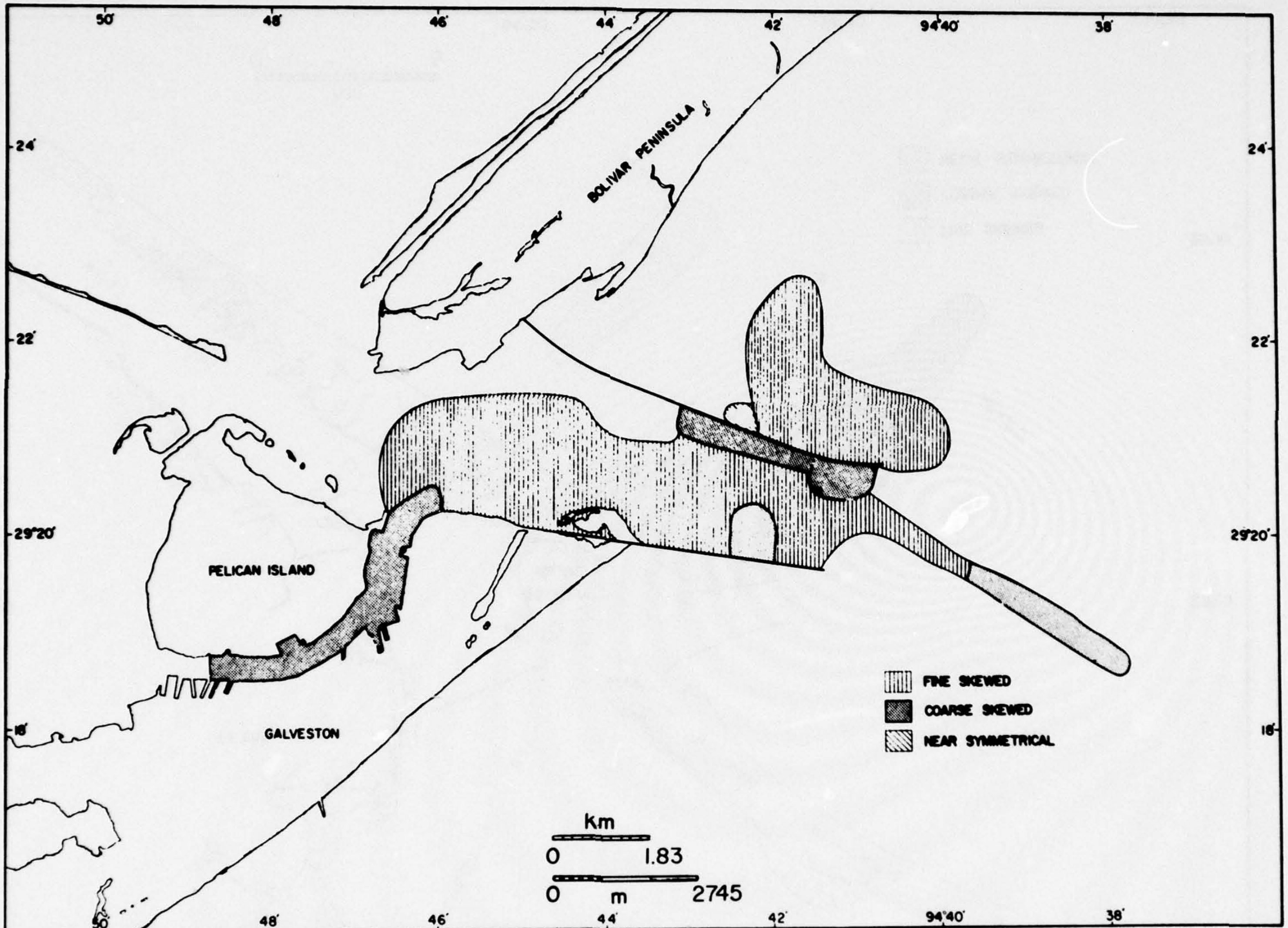


Figure 28. Sediment skewness distribution, Galveston Jetties and surrounding area, predisposal study

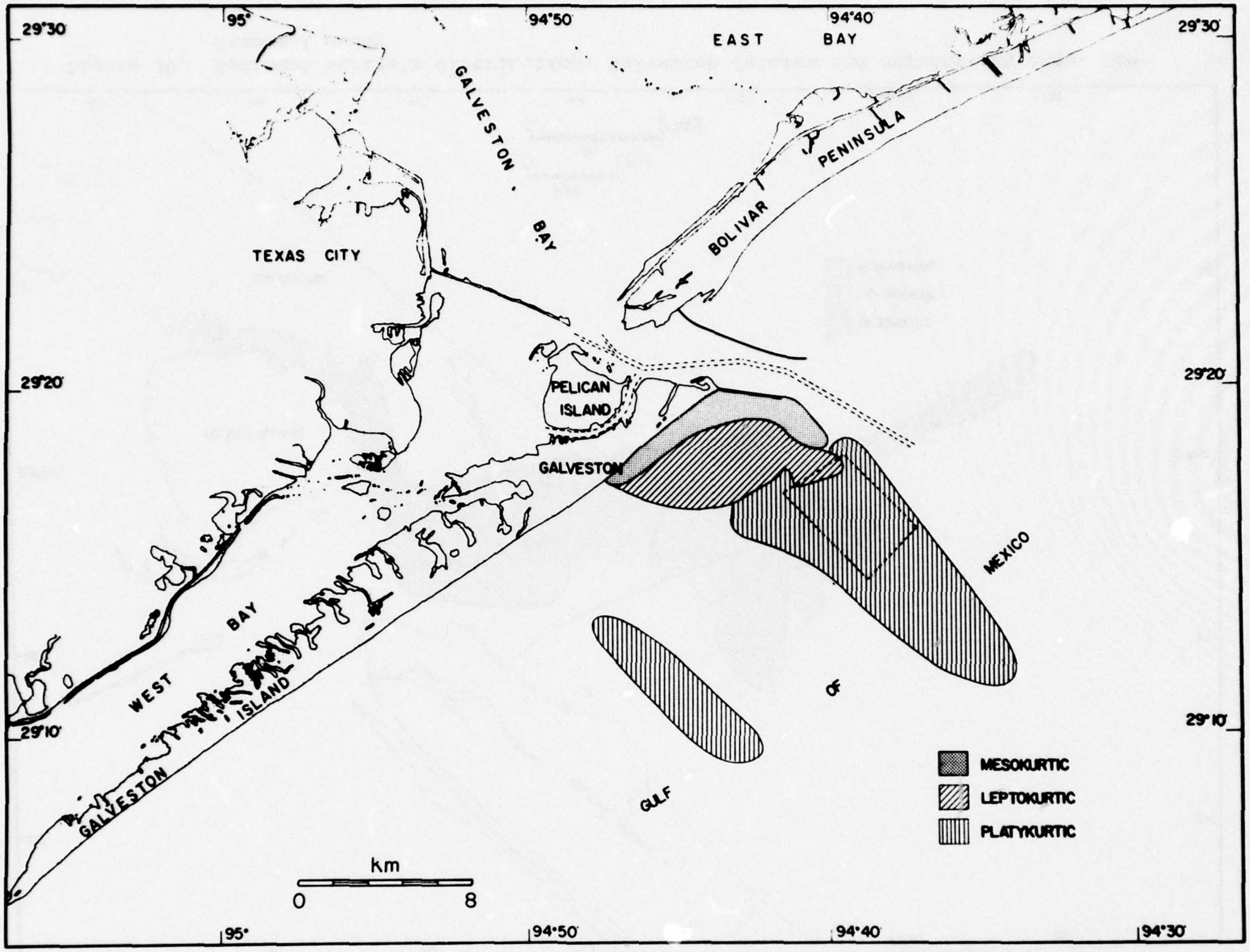


Figure 29. Sediment kurtosis distribution, DMDS and surrounding area, predisposal study

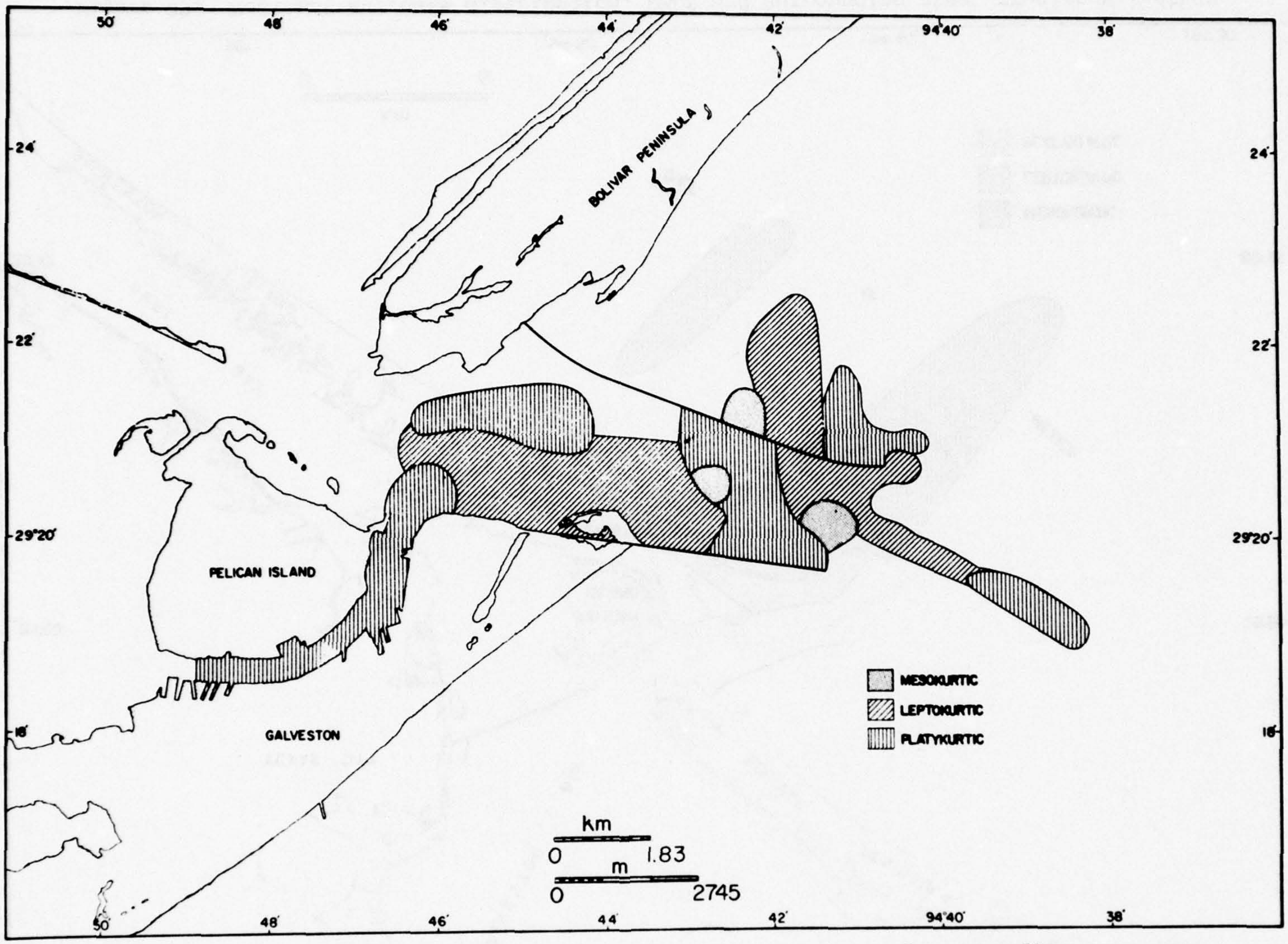


Figure 30. Sediment kurtosis distribution, Galveston Jetties and surrounding area, predisposal study

variability in the relative size fractions of collected samples. This was particularly evident during the December sampling period in which sand percentages varied from a low of 9.9 to a maximum of 98.7 percent. Table 3 also illustrates that the sediment character varied through time. September samples contained 82 percent sand; October, 69 percent; and November, almost 98 percent sand.

53. Samples obtained at the buoy C site for the period September-December 1975 revealed the following. September samples contained 96 percent sand-sized or larger material. Bouma and Huebner[20] reported that October samples contained 92 percent sand and the shell content had increased 25 percent, which led them to conclude that winnowing had occurred. November duplicate samples contained clasts of Beaumont Clay, which at least partially accounted for the lower sand (38 and 55 percent) content. The sand content of December samples was too variable (3 to 98 percent) for any meaningful interpretation.

54. The sediments at the buoy D site showed little change in physical characteristics for the period September-December 1975. The most notable characteristic of the buoy D site was the appreciable amounts of Beaumont Clay clasts found during this period.

55. Sediment samples were collected during January, March, and May 1976 concomitant with biological sampling. Table 4 illustrates the sediment character of samples collected near buoys B (samples 2-1-A to 2-5-E), C (samples 12-1-A to 12-5-E), and D (samples 14-1-A to 14-5-E) and control sites 15 (samples 15-1-A to 15-5-E) and 27 (samples 27-1-A to 27-5-E) during this period. Table 4 indicates the high variability between subsampling stations at each site, and also between duplicate samples at each location. As an example, samples 2-3-A, 2-3-C, and 2-3-E (see Figures 31, 32, and 33 for sample locations) ranged between 30.1-49.4 percent clay, 28.9-51.0 percent sand, and between 6.57-8.57 Ø in mean grain size. Obviously, the sediments within the sampling array near buoy B and duplicate subsamples from the same station are difficult, if not impossible, to interpret through time. As was mentioned previously, the vessel was anchored while samples were collected, and the variability described above is natural, not a func-

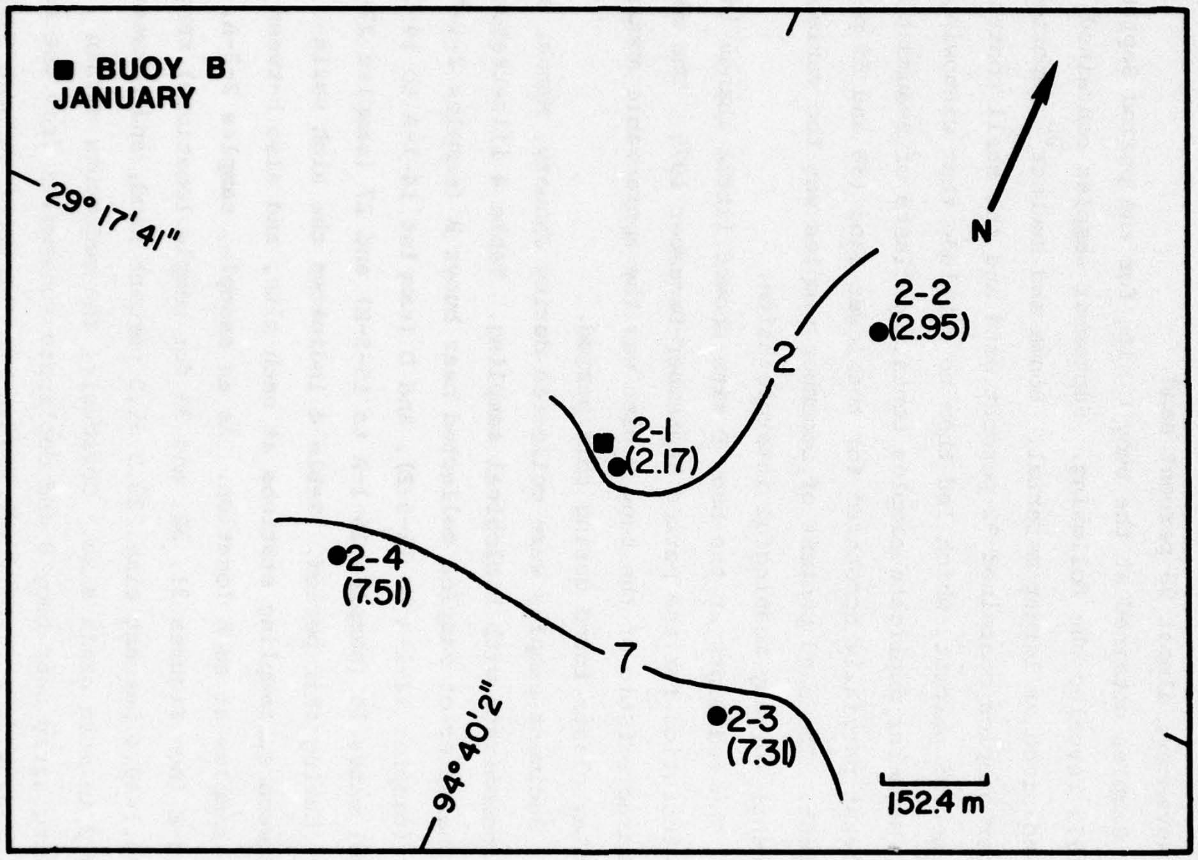


Figure 31. Average mean sediment size (Ø units) and sample locations, buoy B site; January 1976

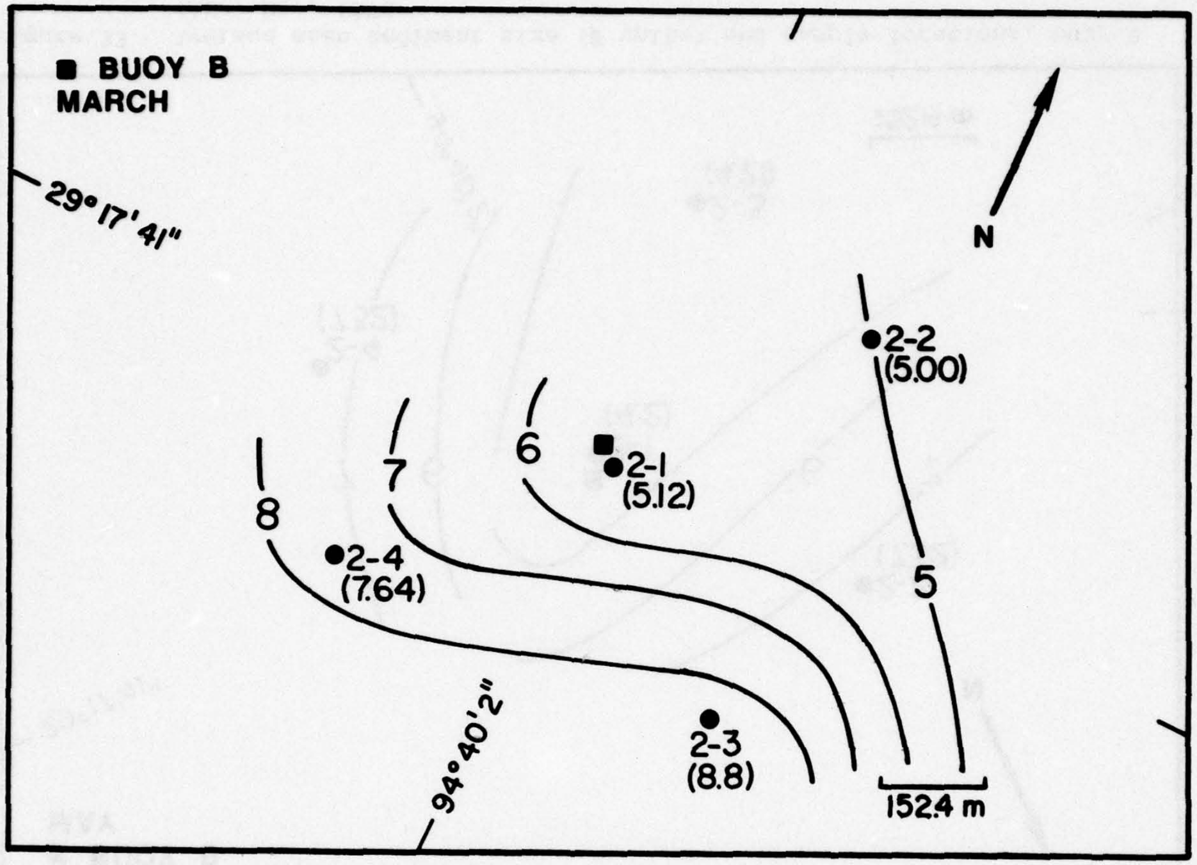


Figure 32. Average mean sediment size (Ø units) and sample locations, buoy B site; March 1976

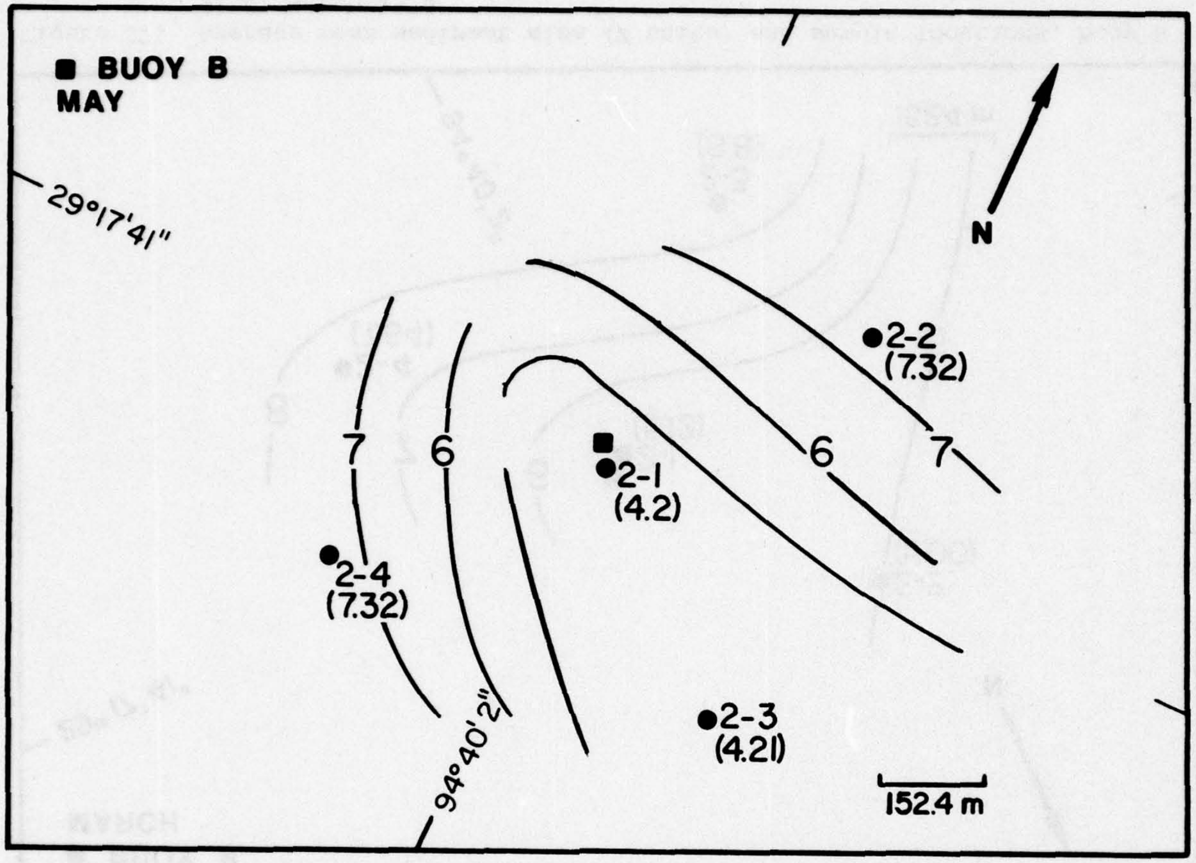


Figure 33. Average mean sediment size (Ø units) and sample locations, buoy B site; May, 1976

tion of changes in sampling location.

56. Buoy B. Figures 31-39 represent an attempt to portray sedimentological differences at buoy sites B, C, and D through the period January-May 1976. These figures depict contoured values of averaged mean sediment size for each disposal area. As can be seen from Figure 31, January sediments at the buoy B site varied from 2.17 to 7.51 Ø units. In proximity to buoy B (station number 2-1), the average mean size of sampled sediments ranged from about 2-7 Ø, with the mean sediment size becoming progressively finer toward the south. During March (Figure 32), the sediments became progressively finer grained near the disposal mound crest. Disposal of about 211,220 m^3 of dredged material during February and March affected the character of bottom sediments near buoy B. Figure 33 illustrates the averaged mean size distribution of sediments sampled during May 1976. In general, sediments became increasingly coarser grained relative to the March sampling. It also appears from data collected during that period that the sediments became increasingly coarser grained toward the southeast. The sediment at the buoy B site had undergone considerable sedimentological change during the period of January-May 1976; in general, the average mean grain size decreased.

57. Buoy C. Figures 34 through 36 illustrate the average mean sediment size (Ø units) of samples collected in proximity to buoy C during the period January-May 1976. January sediment samples ranged from 1.54 Ø units nearest the buoy to 9.38 Ø units northwest of the marker buoy (Figure 34). By March sediments had become slightly finer grained (2.82 Ø units) nearest the buoy. A general decrease in average mean size is also evident from data collected at the other sampling stations. The westernmost sampling station experienced the greatest change (5.59 to 9.05 Ø).

58. May samples indicated a general coarsening of bottom sediments at the buoy C site. Mean sediment size increased to 0.28 Ø unit nearest the marker buoy. Maximum change occurred to the west of the buoy (9.05-1.8 Ø).

59. Buoy D. Mean sediment size data determined from samples from

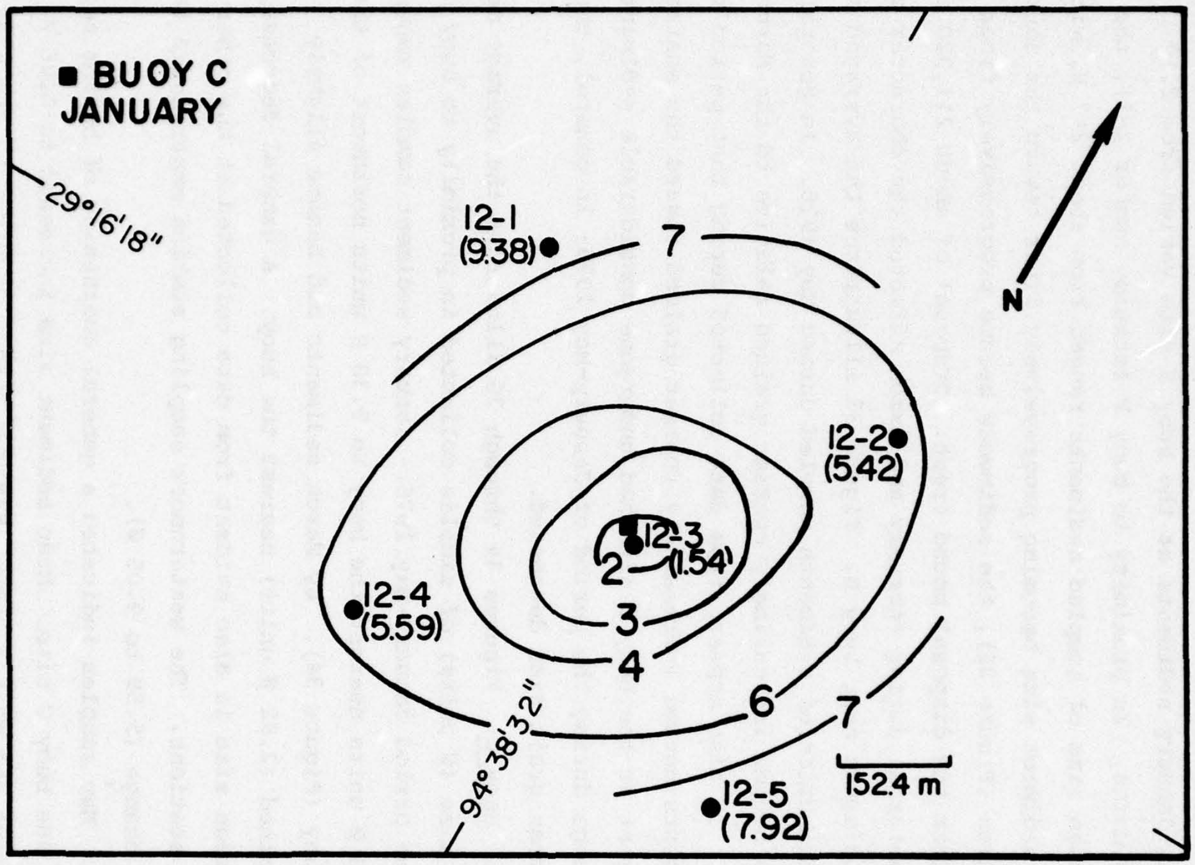


Figure 34. Average mean sediment size (Ø units) and sample locations, buoy C site; January, 1976

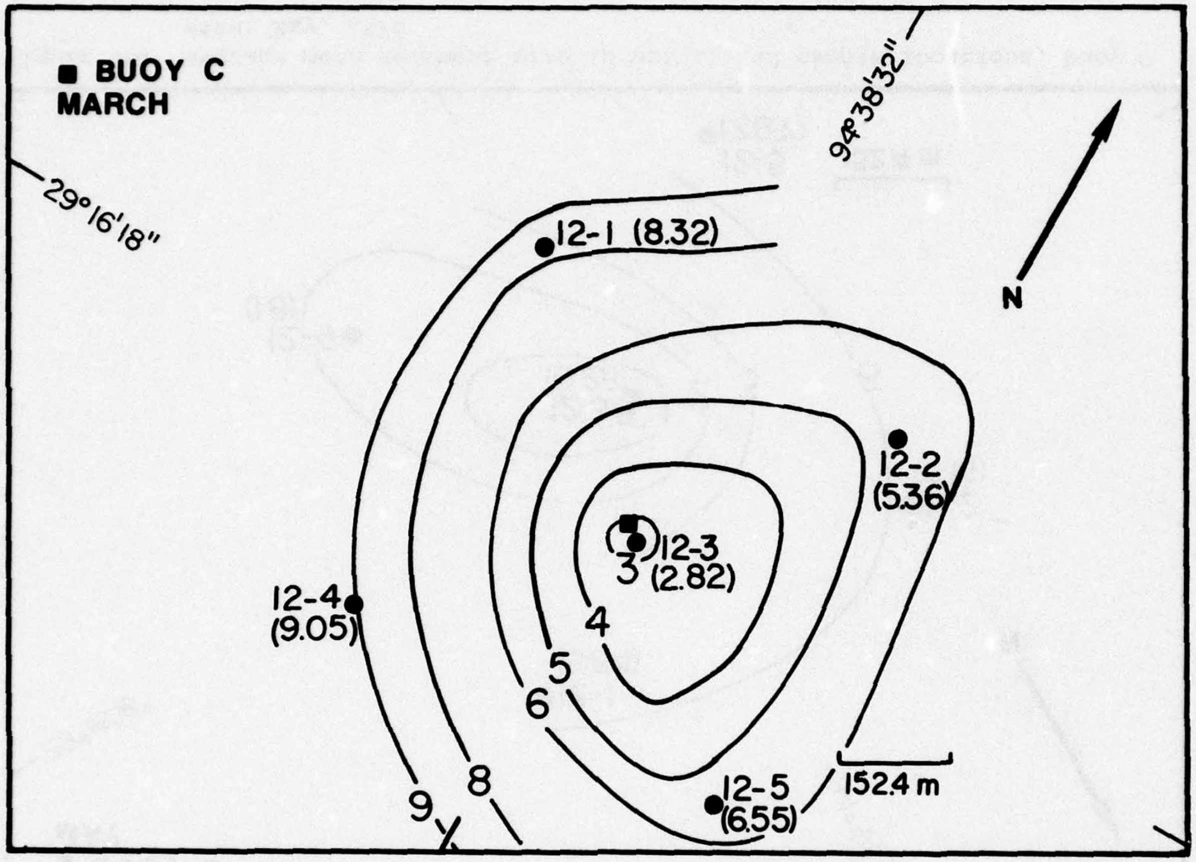


Figure 35. Average mean sediment size (Ø units) and sample locations, buoy C site; March, 1976

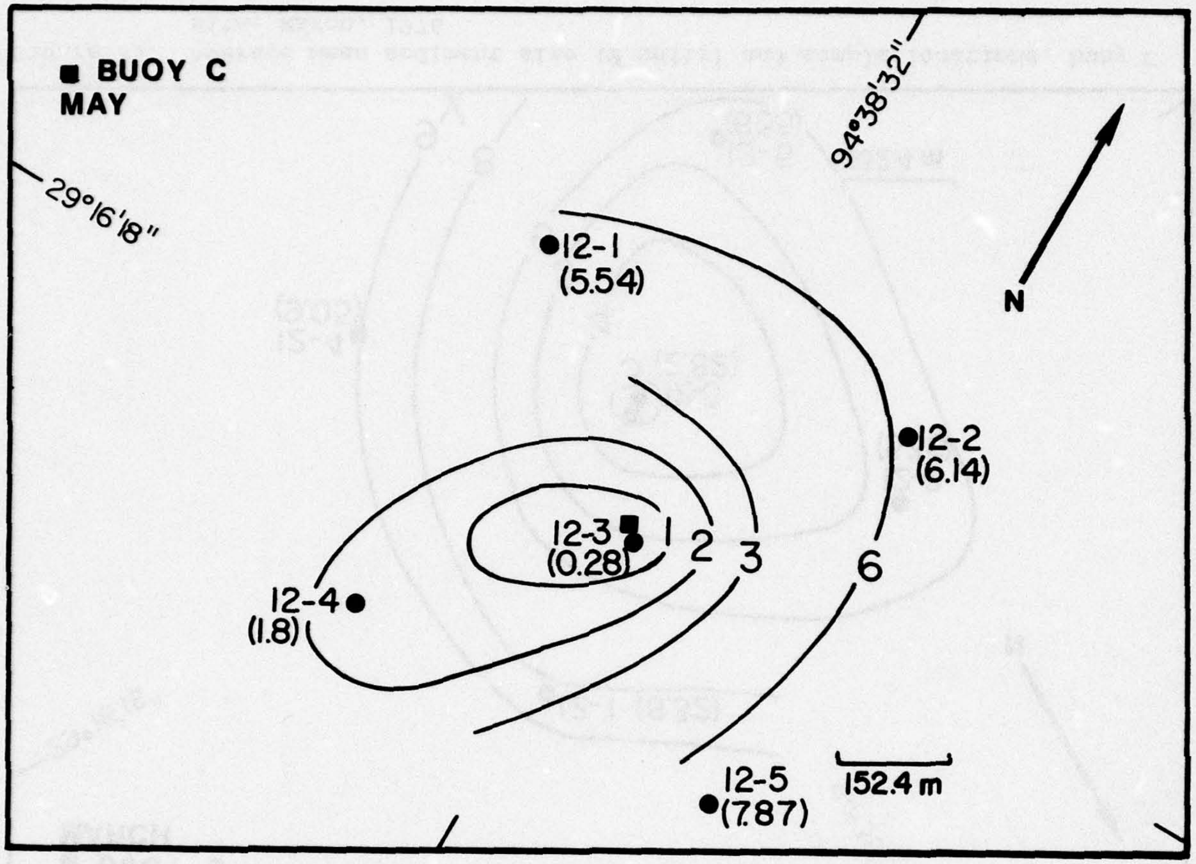


Figure 36. Average mean sediment size (Ø units) and sample locations, buoy C site; May, 1976

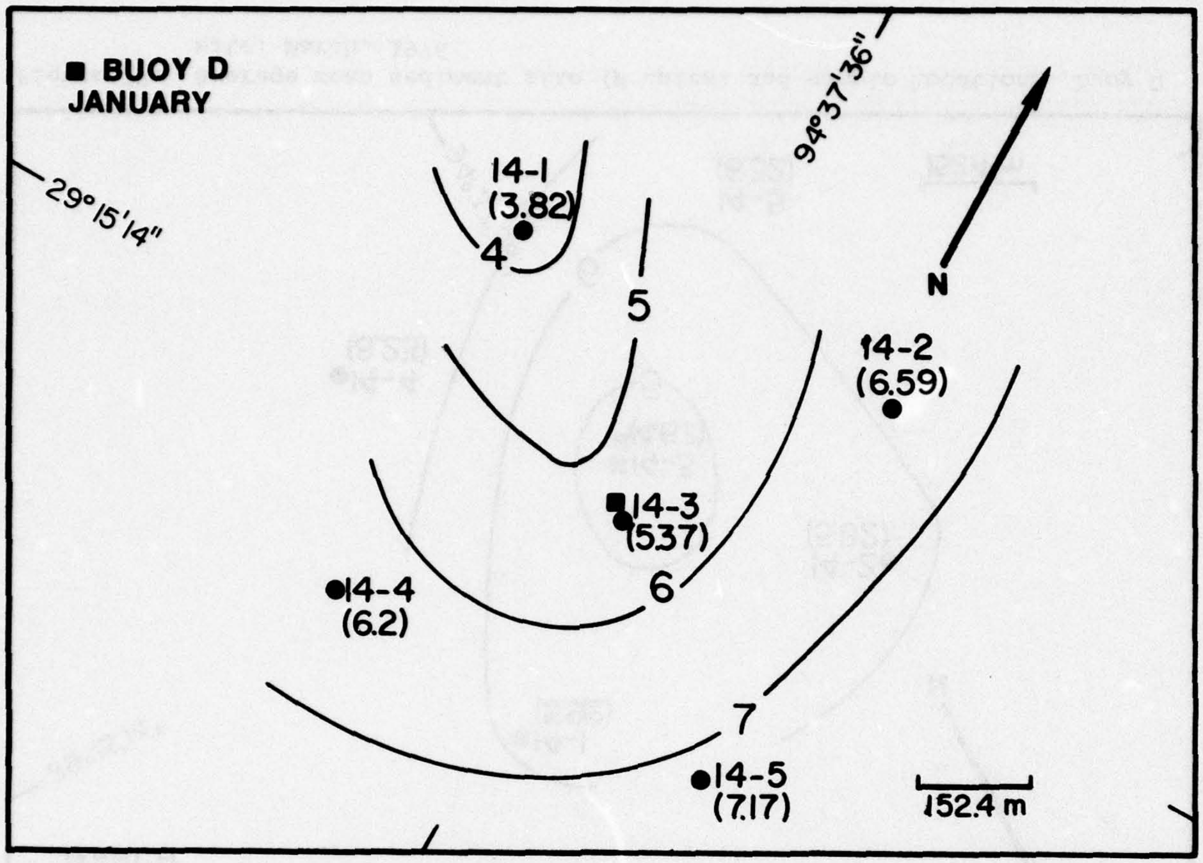


Figure 37. Average mean sediment size (Ø units) and sample locations, buoy D site; January, 1976

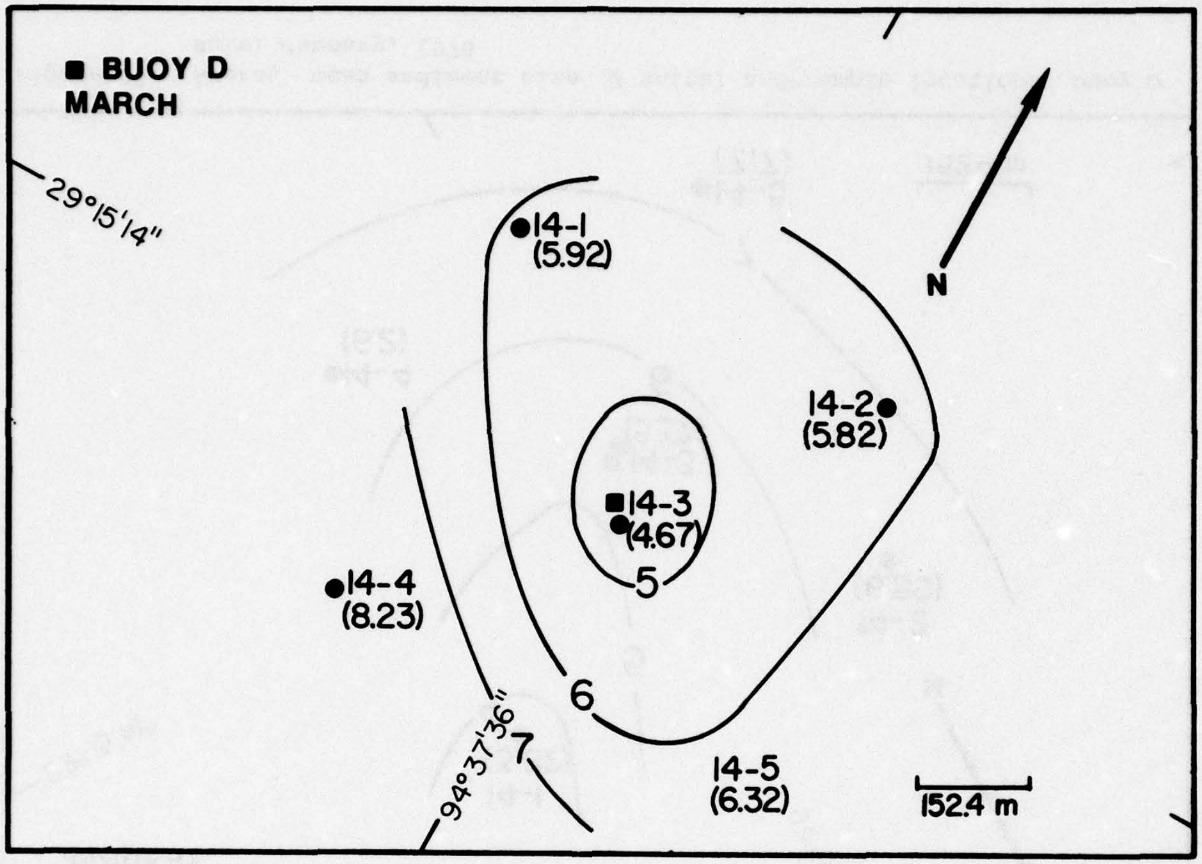


Figure 38. Average mean sediment size (Ø units) and sample locations, buoy D site; March, 1976

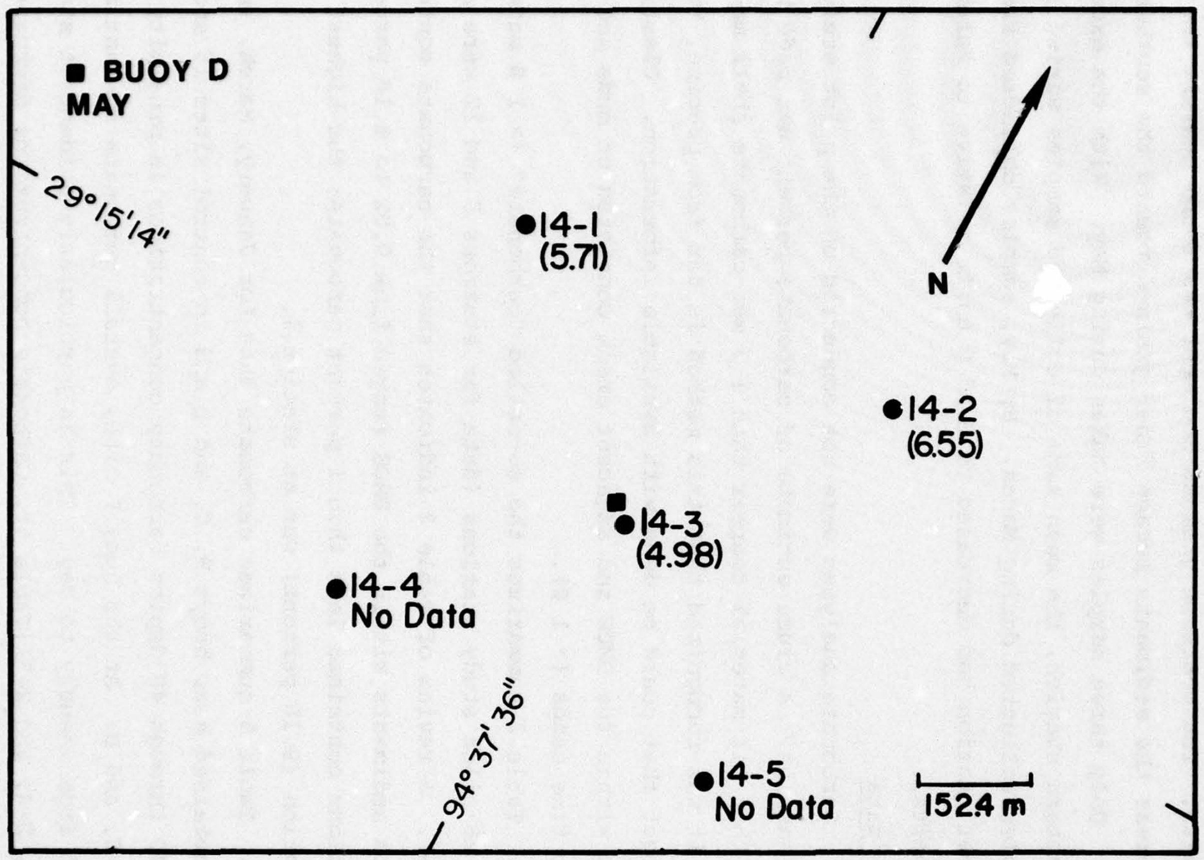


Figure 39. Average mean sediment size (Ø units) and sample locations, buoy D site; May, 1976

the buoy D site during January ranged from 3.82-7.17 Ø. Nearest the buoy, bottom sediments consisted of 5.37 Ø-sized material. The coarsest sediment was sampled from the northwestern sampling station.

60. Little sediment change was evident from samples collected during March. The March mean sediment sizes ranged from 4.67 Ø to 8.23 Ø units. The coarsest grained sediment was found nearest the buoy, whereas the sediments became finer grained toward the southwest.

61. Only three samples were taken during May. With the exception of the eastern station, the mean size of collected samples varied little from samples collected during March. By May, samples collected from the easternmost station had decreased to 6.55 Ø units relative to March (5.82 Ø units).

Carbonate data

62. Carbonate analyses were not conducted on the pilot study sediment samples. A crude estimate of carbonate percent was made by assuming that all material coarser than 1 Ø was carbonate shell material. It was recognized that this method is far from precise, but it was the best that could be done with available information. Clastic sediments within the DMDS and adjacent areas consisted of muds and medium to fine sands (> 1 Ø).

63. Table 2 summarizes the so-called "carbonate" (> 1 Ø material) data for 26 pilot study stations (data for stations 5 and 12 were not available). A review of Table 2 indicates that the carbonate content of the bottom sediments within the DMDS ranged from 0.02 to 9.18 percent. Most stations contained less than 1 percent carbonate; the highest concentration (9.18 percent) was at station 1.

64. Table 5 summarizes carbonate data for January, March, and May samples obtained near buoys B, C, and D and in control sites 15 and 27. Figures 40 through 48 depict carbonate concentrations in proximity to buoys B, C, and D. At the buoy B site, overall carbonate concentration decreased from January to May. This is particularly evident at stations 2-1, 2-2, 2-4, and 2-5 (Table 5). Carbonate concentrations decreased from a January high of 33.5 percent to a May low of 1.8 percent. Maximum carbonate change occurred nearest the disposal mound crest (station

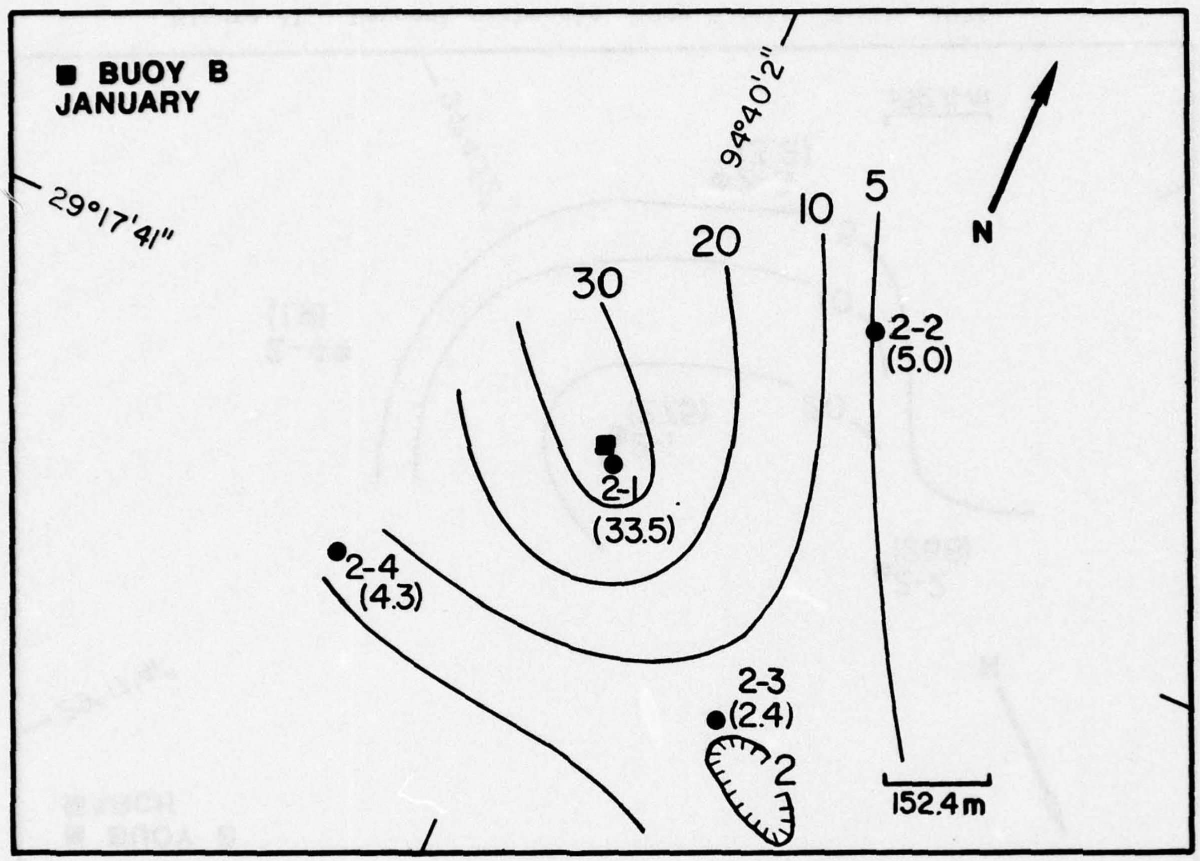


Figure 40. Percent carbonate, buoy B site; January, 1976

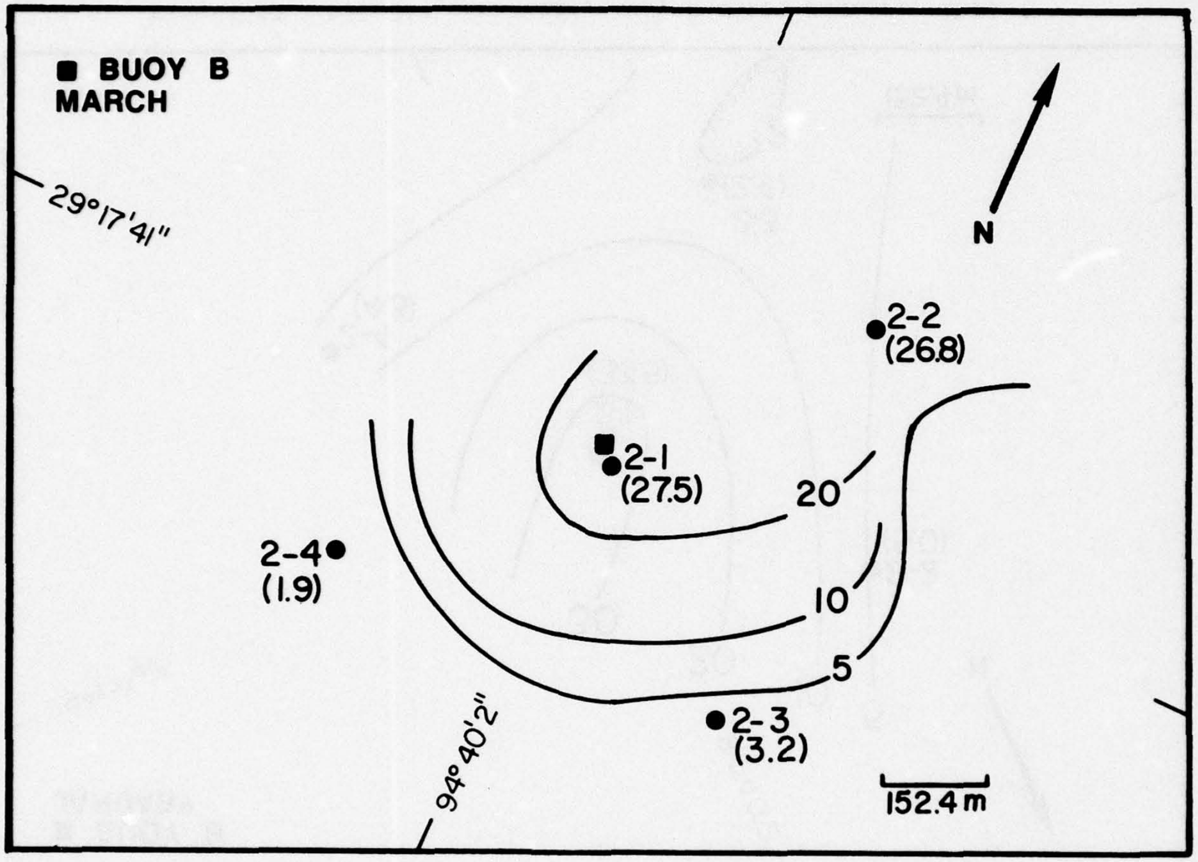


Figure 41. Percent carbonate, buoy B site; March, 1976

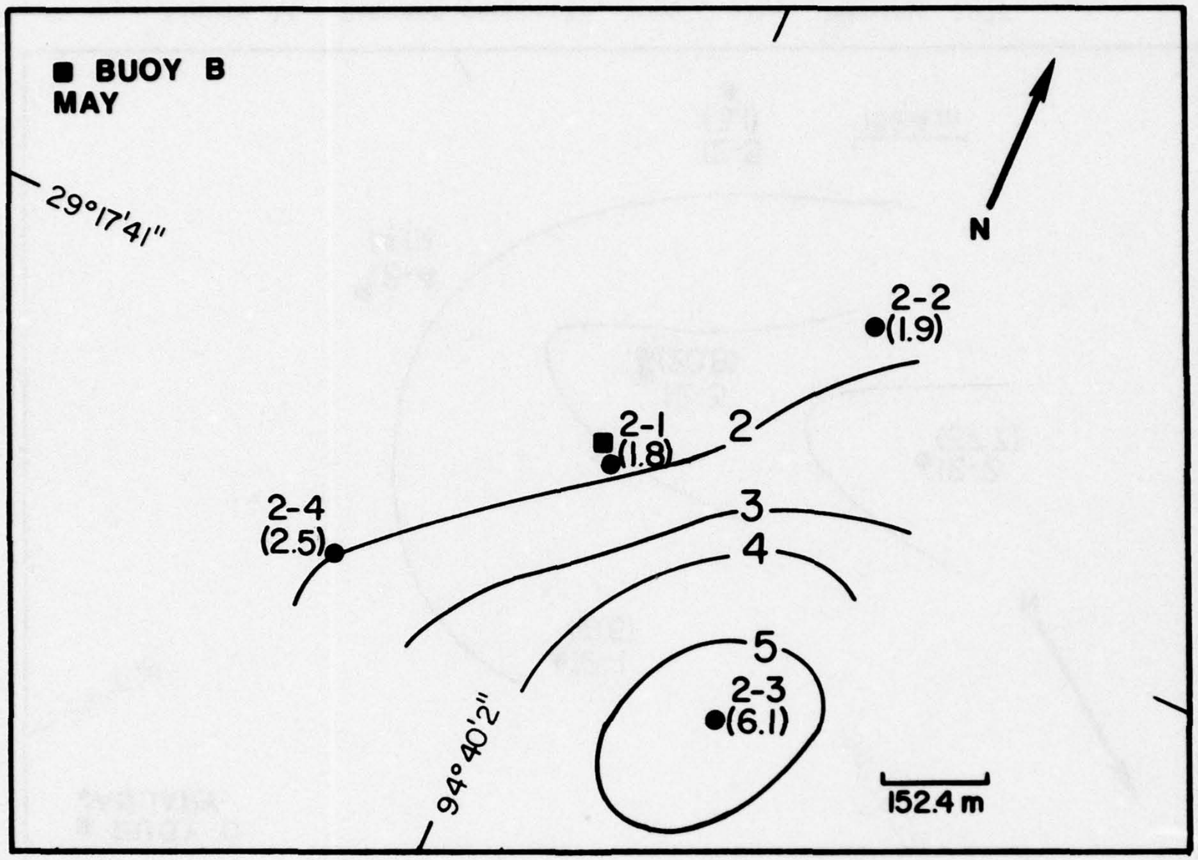


Figure 42. Percent carbonate, buoy B site; May, 1976

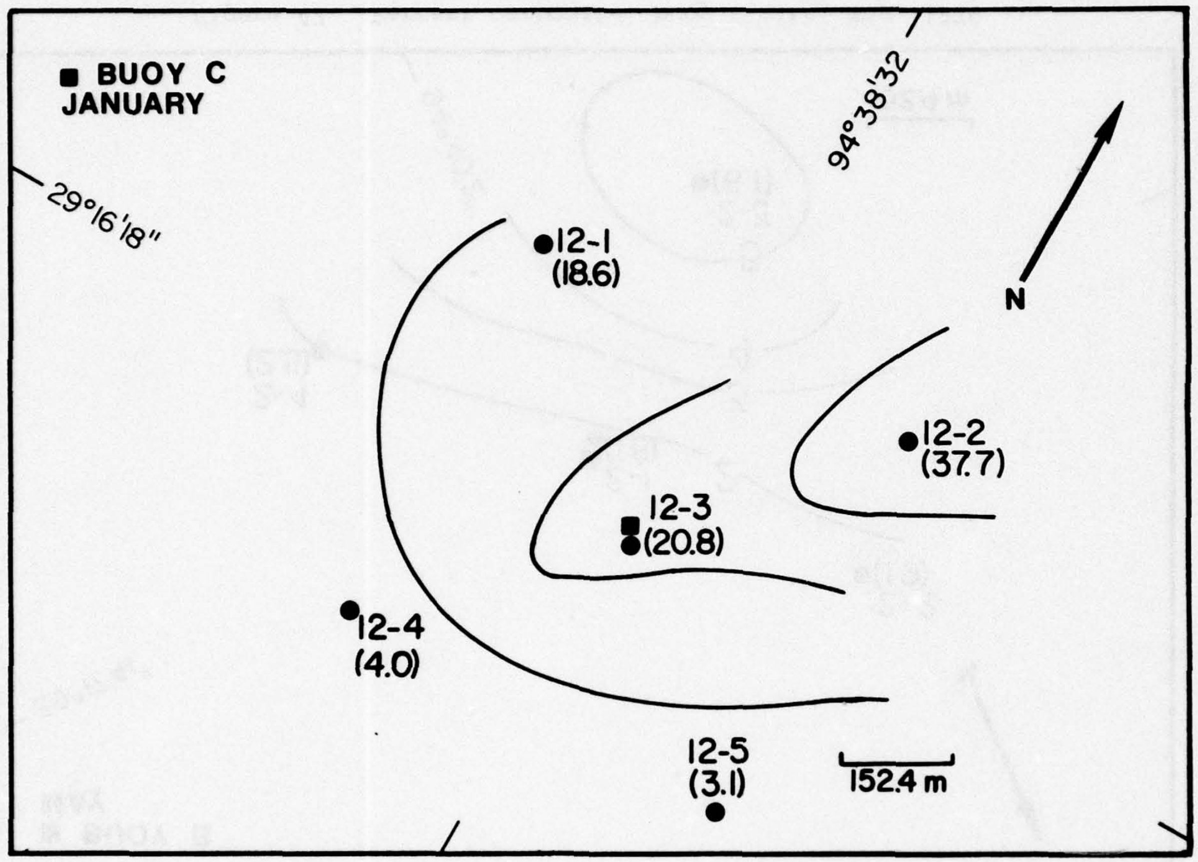


Figure 43. Percent carbonate, buoy C site; January, 1976

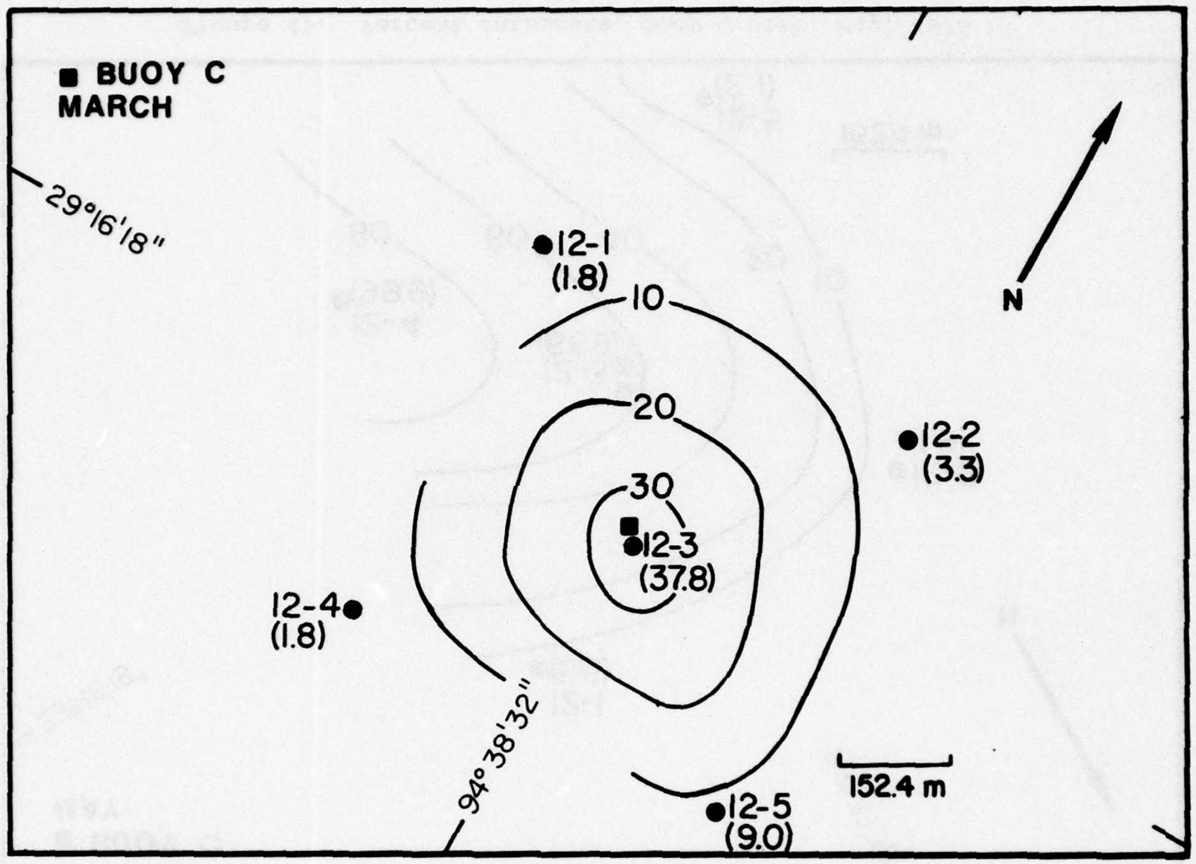


Figure 44. Percent carbonate, buoy C site; March, 1976

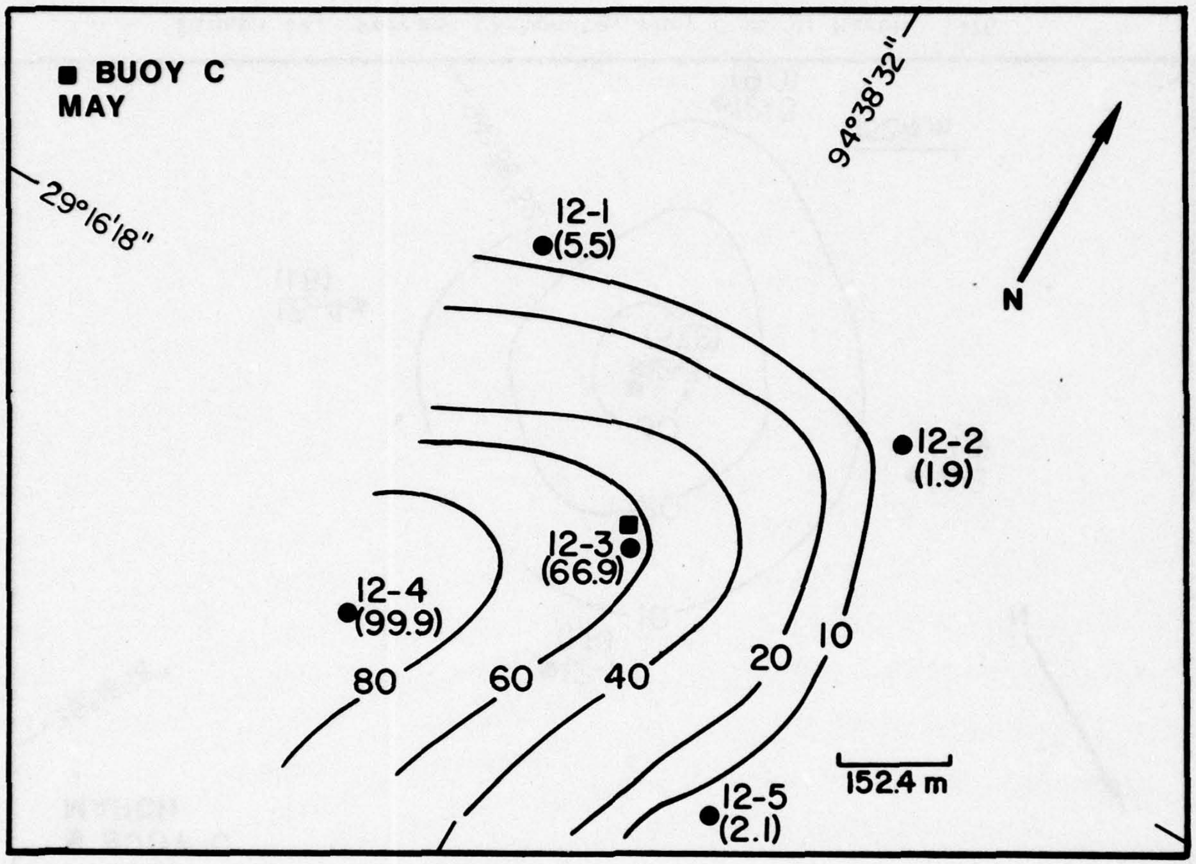


Figure 45. Percent carbonate, buoy C site; May, 1976

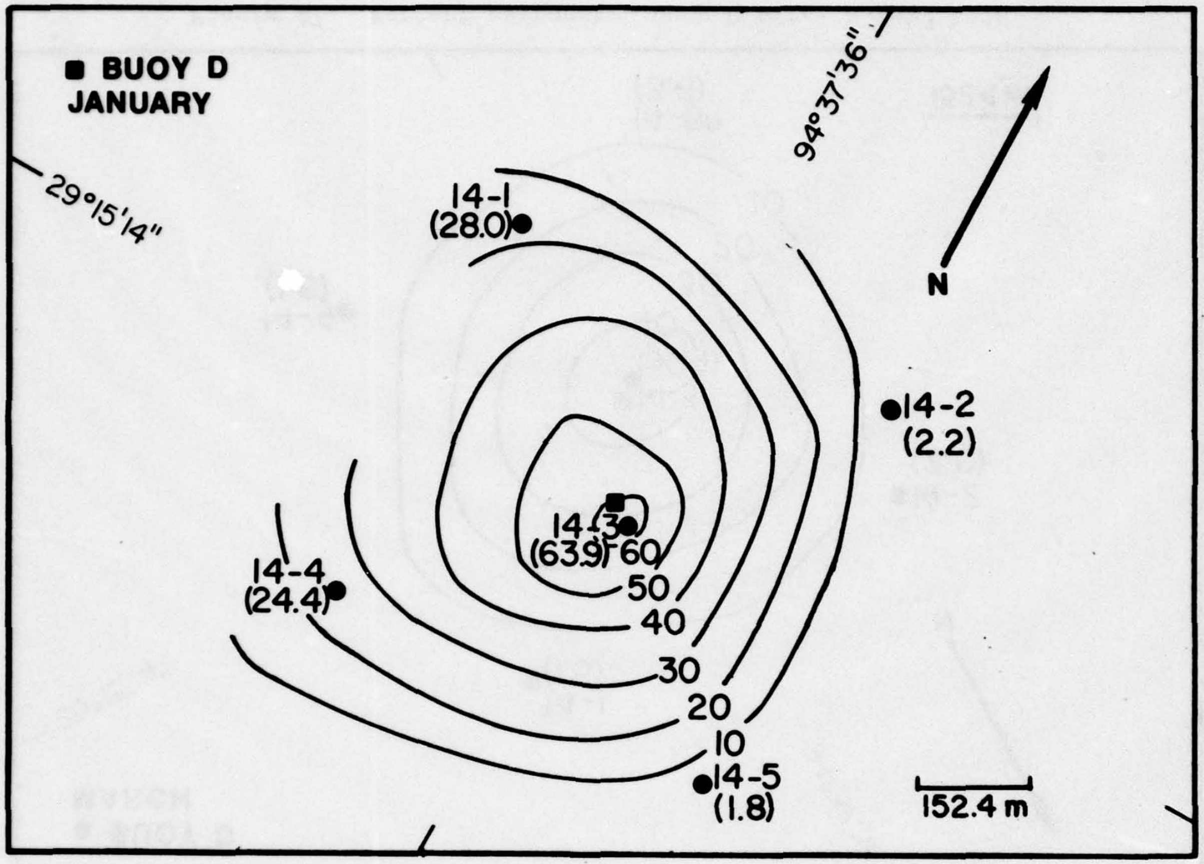


Figure 46. Percent carbonate, buoy D site; January, 1976

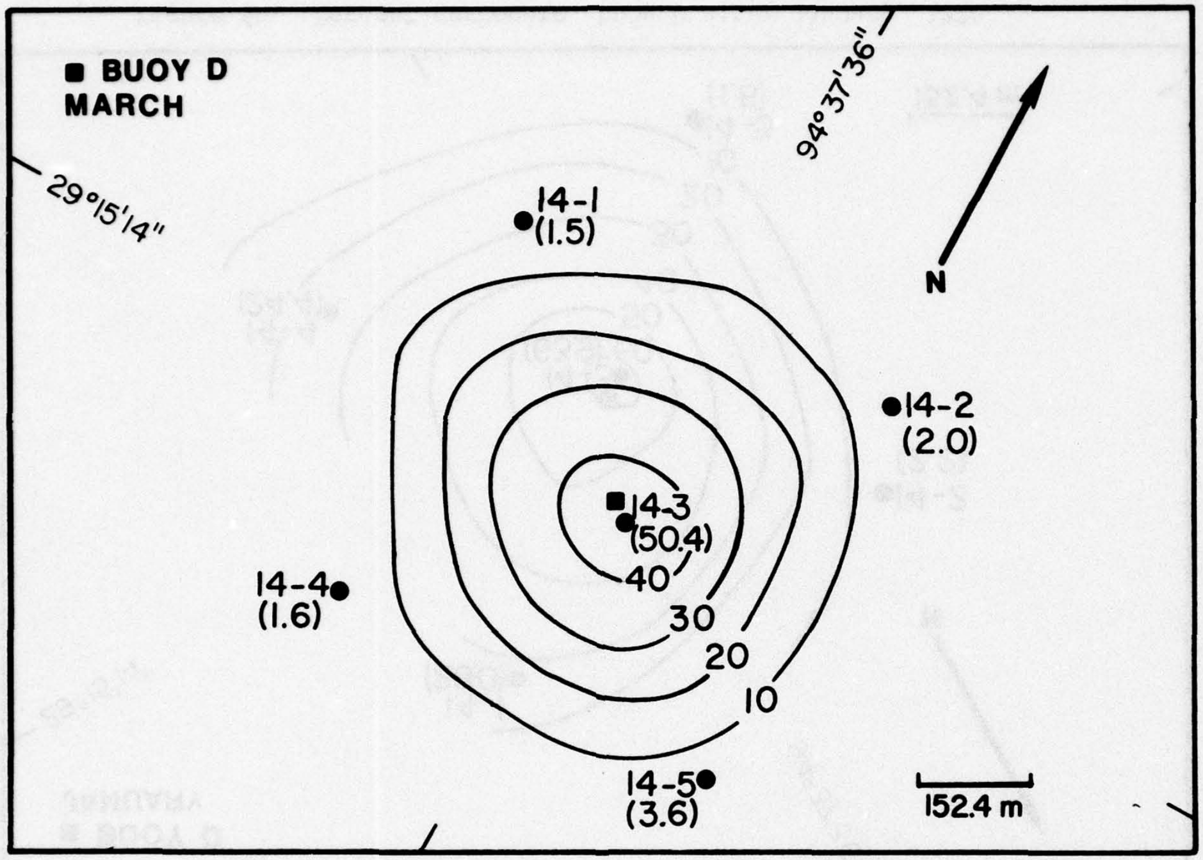


Figure 47. Percent carbonate, buoy D site; March, 1976

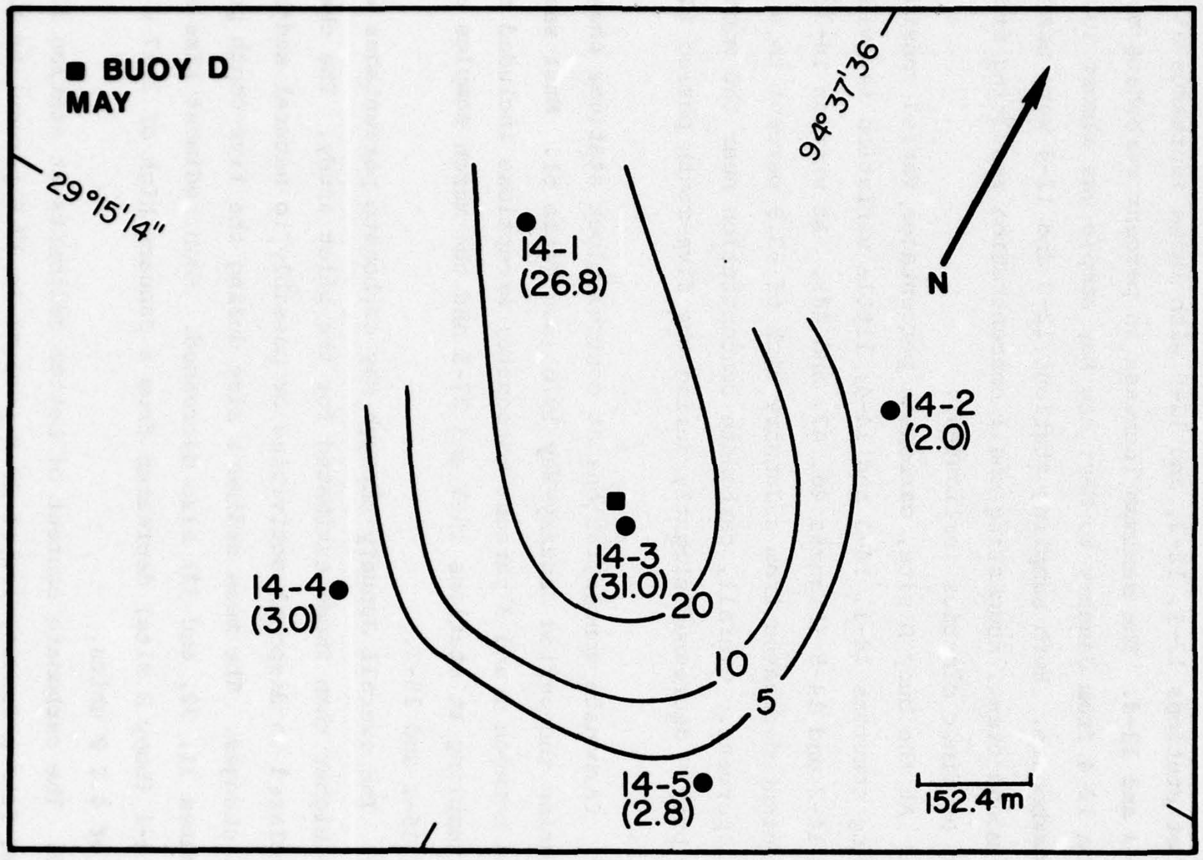


Figure 48. Percent carbonate, buoy D site; May, 1976

2-1) at buoy B during this five-month period.

65. Carbonate concentration in samples from the buoy C site (stations 12-1 to 12-5) increased at station 12-3 during the January through May sampling period (see Table 5; Figures 43, 44, and 45). Fluctuations are evident from January to March and May, but the overall trend was a decrease at stations 12-1, 12-2, and 12-5 with large increases at stations 12-3 and 12-4. The maximum increase in percent carbonate occurred at station 12-4 from January to May; the May sample was almost 100 percent carbonate. Both sampling stations 12-3 and 12-4 were near the disposal mound crest, suggesting shell concentration resulting from winnowing of finer clastics (silicates).

66. At the buoy D site, carbonate percentages varied considerably at sampling stations 14-1, 14-3 and 14-4; little variation is evident at stations 14-2 and 14-5 (Figures 46, 47, and 48). At station 14-3, carbonate content decreased from a January high of 63.9 percent to a May low of 31 percent. Overall, carbonate concentration near the mound crest at buoy D decreased slightly during the five-month period (January-May).

67. Carbonate concentrations at control block stations changed little during the period January-May 1976 (see Table 5). Most samples contained between 1 and 3 percent carbonate; exceptions included the January sampling at stations 15-1 and 27-5 and the March samples at stations 15-2 and 15-3.

68. The overall January through May carbonate percentages were slightly higher than those estimated for the pilot study. The changes may be related to disposal activities or possibly to natural sedimentological changes. The mean sediment size during the five-month period (see Figures 31, 32, and 33) also decreased. Mean sediment size at station 2-1 (buoy B site) decreased from a January high of 2.17 Ø to a May low of 4.2 Ø units.

69. The carbonate content of bottom sediments at station 12-3 increased from a January low of 20.8 percent to 37.8 percent by March and to 66.9 percent by May. The mean grain size of bottom sediments of the area also reflects a major change in sediment character

at the buoy C site. Mean size of sediments at buoy C (12-3) varied from 1.54 Ø during January to 2.82 Ø during March, and increased to 0.28 Ø by May. This change paralleled the increased carbonate concentrations of 20.8 to 66.9 percent.

70. The overall carbonate concentrations at the buoy D site decreased during the period January-May 1976. Little correlation can be found between carbonate and average mean size of sampled bottom sediments; in fact, the average mean size of sampled bottom sediments increased slightly (5.37-4.98 Ø) over the five-month sampling period.

Sediment tracer experiment

71. The actual transport of sand-sized material at the buoy B site was documented by the sampling of previously released dyed tracer sands. The dominant sediment transport direction 24 hr (Figure 49) and 48 hr (Figure 50) after release of tracer sands (11 November 1975) was to the west. A second tracer study (12-14 December 1975), also carried out at the buoy B site under higher velocity current conditions, indicated a southwesterly transportation and dispersion trend (Figure 51).

Remote sensing

72. Information obtained from overflight photographs taken during dredged material disposal operations has been discussed by Bouma and Huebner.[20] They noted a loss of suspended material from the hopper dredge during transport to the DMDS and continued loss of dredged material from the hopper dredge after disposal. The initial loss was believed due to leakage from the hopper, while the latter loss was believed due to residual sediments being released from the dredge. In addition, at each observed disposal operation, a distinctive plume (assumed to be mainly clay- and silt-sized material) was observed which dispersed rapidly down current at speeds of up to 31 cm/sec. Suspended sediment data presented by Bouma and Huebner[20] indicated that a density current (or mudflow) formed from the finer fractions of the disposed material and could be detected as increased suspended material in the water mass for up to two weeks after dredged material disposal.

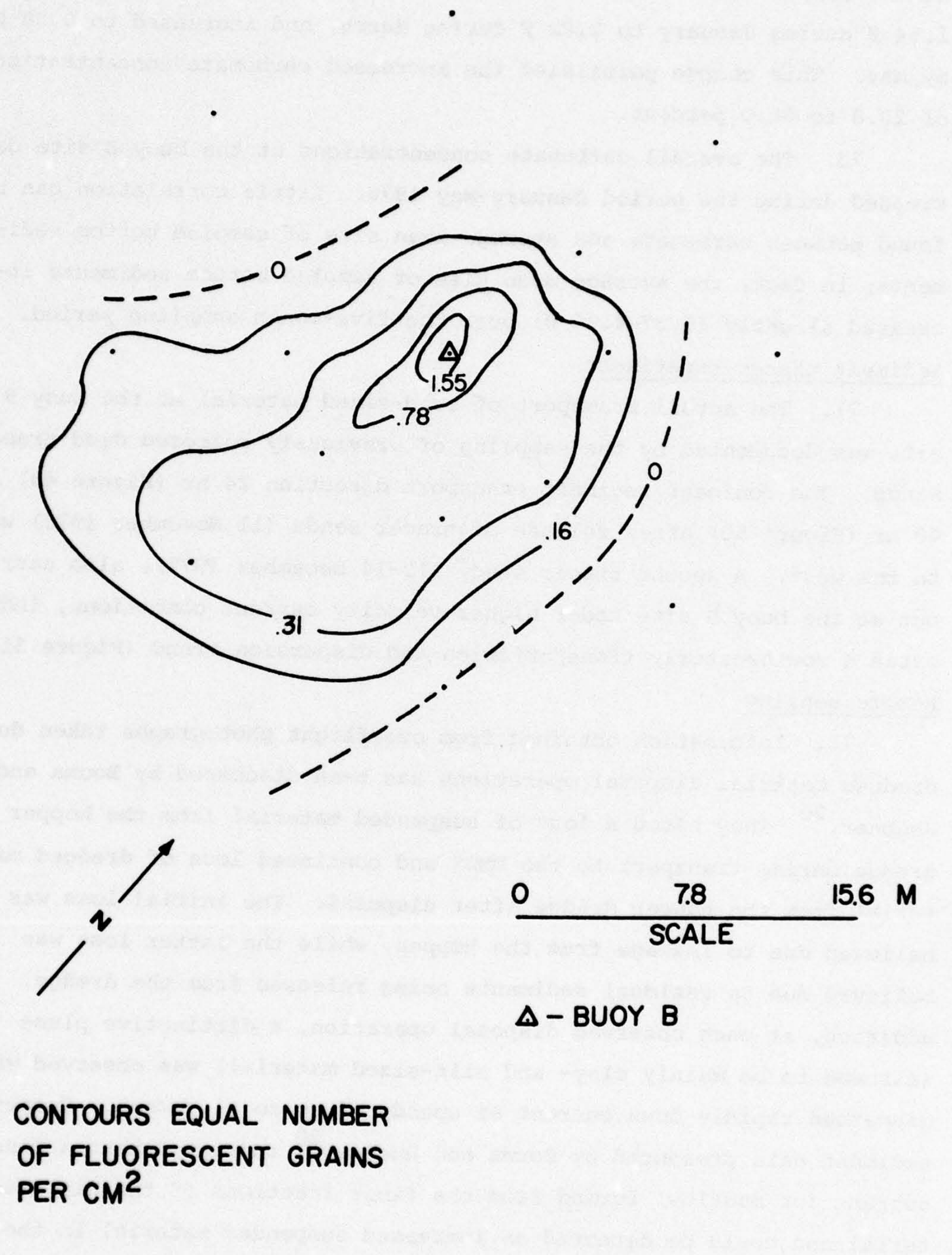
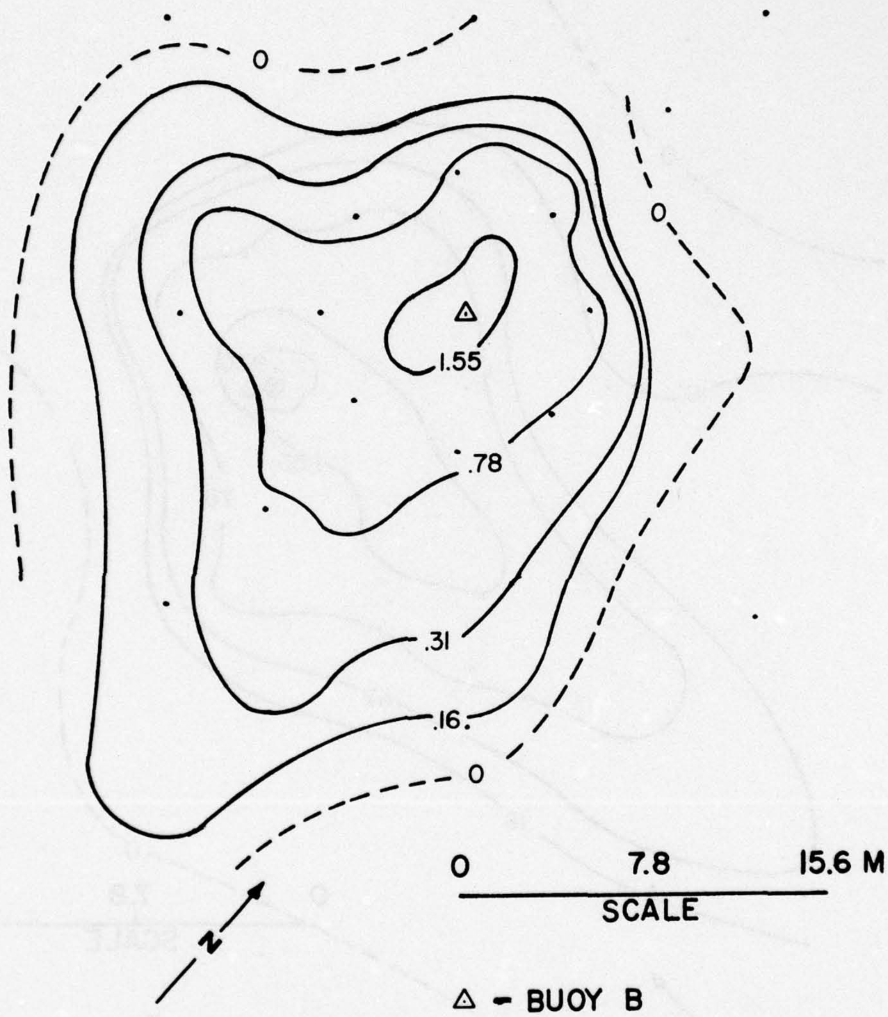


Figure 49. Tracer sand dispersion at the buoy B site, 24 hr after release; 12 November, 1975



CONTOURS EQUAL NUMBER OF FLUORESCENT GRAINS PER CM^2

Figure 50. Tracer sand distribution at the buoy B site, 48 hr after release; 13 November, 1975

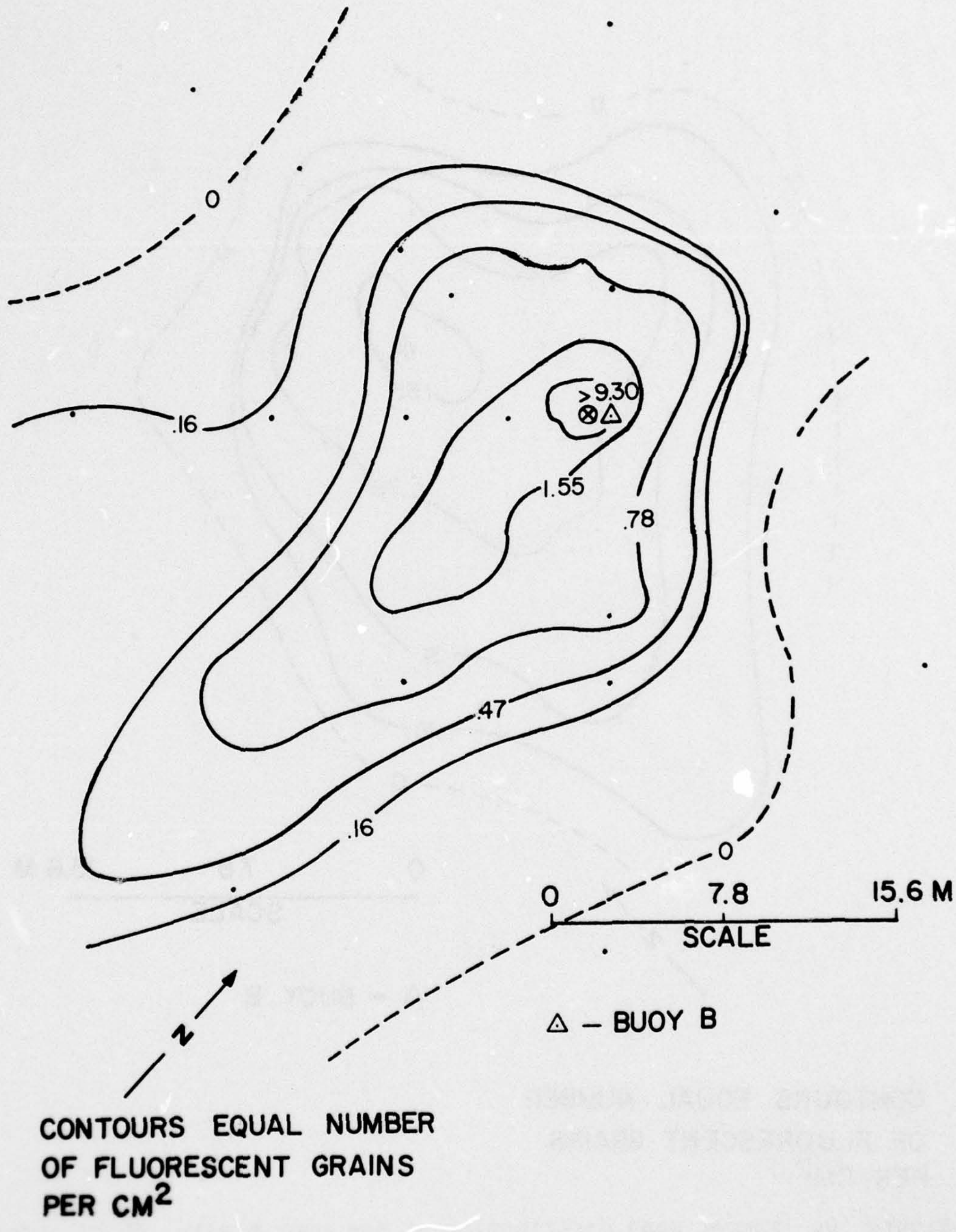


Figure 51. Tracer sand dispersion at the buoy B site, 48 hr after release; 14 December, 1975

Control Sites

73. To evaluate the erosion and deposition of disposal mounds at sites B, C, and D, it was necessary to understand the natural sedimentological changes that would have occurred had dredged material not been placed at these sites. This may be accomplished by:

a. Conducting detailed long-term studies of the DMDS prior to the initiation of disposal activities.

b. Establishing representative control study sites that closely approximate the physical-geological conditions of disposal sites B, C, and D.

The preferred and recommended method is a. supplemented by b. It was originally planned to sample each site for 6 months to a year prior to the first dredged material disposal. However, the research period was shortened and disposal occurred before baseline data were gathered. Thus it was necessary to rely on method b.; control blocks 15 and 27 were sampled concomitantly with the disposal sites. Block 15 was to act as a control for the block 2 (buoy B site) station and block 27 was the control for blocks 12 and 14.

74. Based on pilot study data, buoy B and D sites differed sedimentologically from control sites 15 and 27 (no direct data available from the buoy C area, block 12). The mean sediment sizes at blocks 15 and 27 were 7.1 Ø and 9.1 Ø, respectively, whereas buoy B, C, and D mean sediment sizes were 5.0 Ø, about 6.5 Ø, and 6.0 Ø units, respectively (extrapolated from data presented in Figure 18). The sedimentological characteristics of the buoy sites and control blocks differed initially, at least from the time the pilot study samples were obtained relative to subsequent samplings.

75. Water depths and, therefore, the sedimentological regime differed within the DMDS; block 15 water depths were about 10.6 m -- comparable to the buoy B site, about 11.5 m. Block 27 water depths were about 15.3 m, which approximated water depths at buoy D, about 16 m. Although these areas are geographically close, sedimentological differences between the buoy D site and block 27 were evident.

76. By January 1976 (Figure 52), the mean grain size of bottom

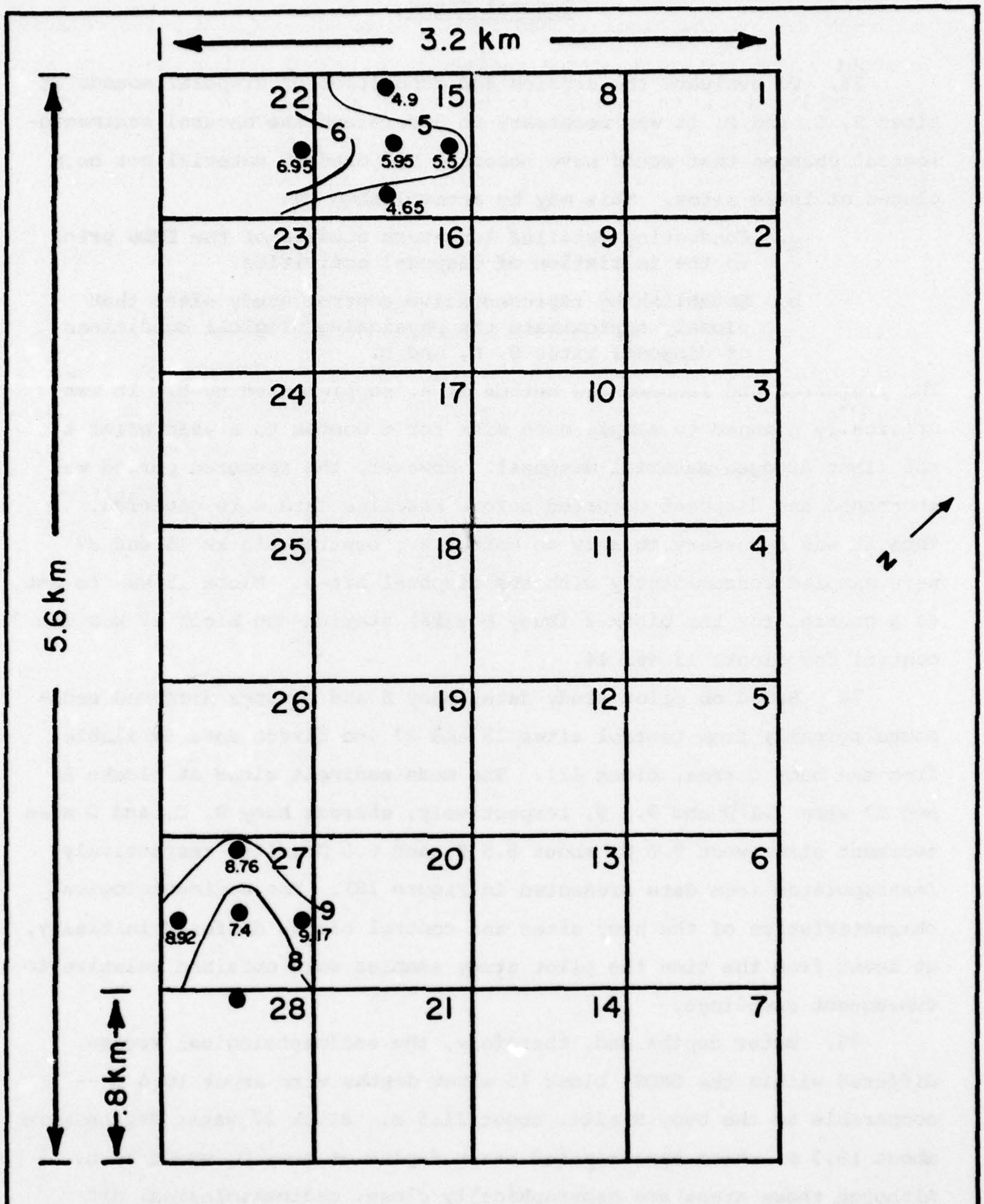


Figure 52. January mean sediment size (Ø units) of control site samples, blocks 15 and 27

sediments in control block 15 had increased to about 6.0 Ø units relative to about 7.0 Ø units for bottom sediments collected during the pilot study. Sediments continued to coarsen through March and May 1976 (Figures 53 and 54), although little change was evident after March; bottom sediments near the center of block 15 stabilized at a mean grain size of about 4.5 Ø.

77. The mean and standard deviation of sediment samples collected near buoys B, C, and D and control sites 15 and 27 were computed and plotted (Figure 55) to determine if any significant difference could be detected for each site during the period January-May 1976. As can be seen from Figure 55, considerable overlap is evident for sites B, C, D, and 15 and little if any sediment change or difference is evident through time. Control site 27 does appear to differ from sites B, C, D, and 15. In general, sediments at site 27 were finer grained, varied less through time than the other four sites, and became slightly finer grained over the five-month period.

Hydraulic Regime

78. Investigations of the movement of dredged material from the disposal site were made in a rectangular circulating flume (Figure 56). The flume was constructed to model the effects of unidirectional turbulent flow on bedload and suspended sand, silt, and clay mixtures obtained from the DMDS. The objectives of this study were to:

a. Determine the critical erosion velocity in terms of bedshear and current speed necessary to erode each sediment mixture.

b. Determine the transport conditions necessary to keep eroded material in suspension.

c. Determine the amount and composition of suspended matter resulting from erosion under controlled current velocities.

d. Determine the relationships describing the recorded sediment erosion and transport in order to predict relative erosion, transport, and deposition in the DMDS.

e. Evaluate the hydrographic data acquired within and

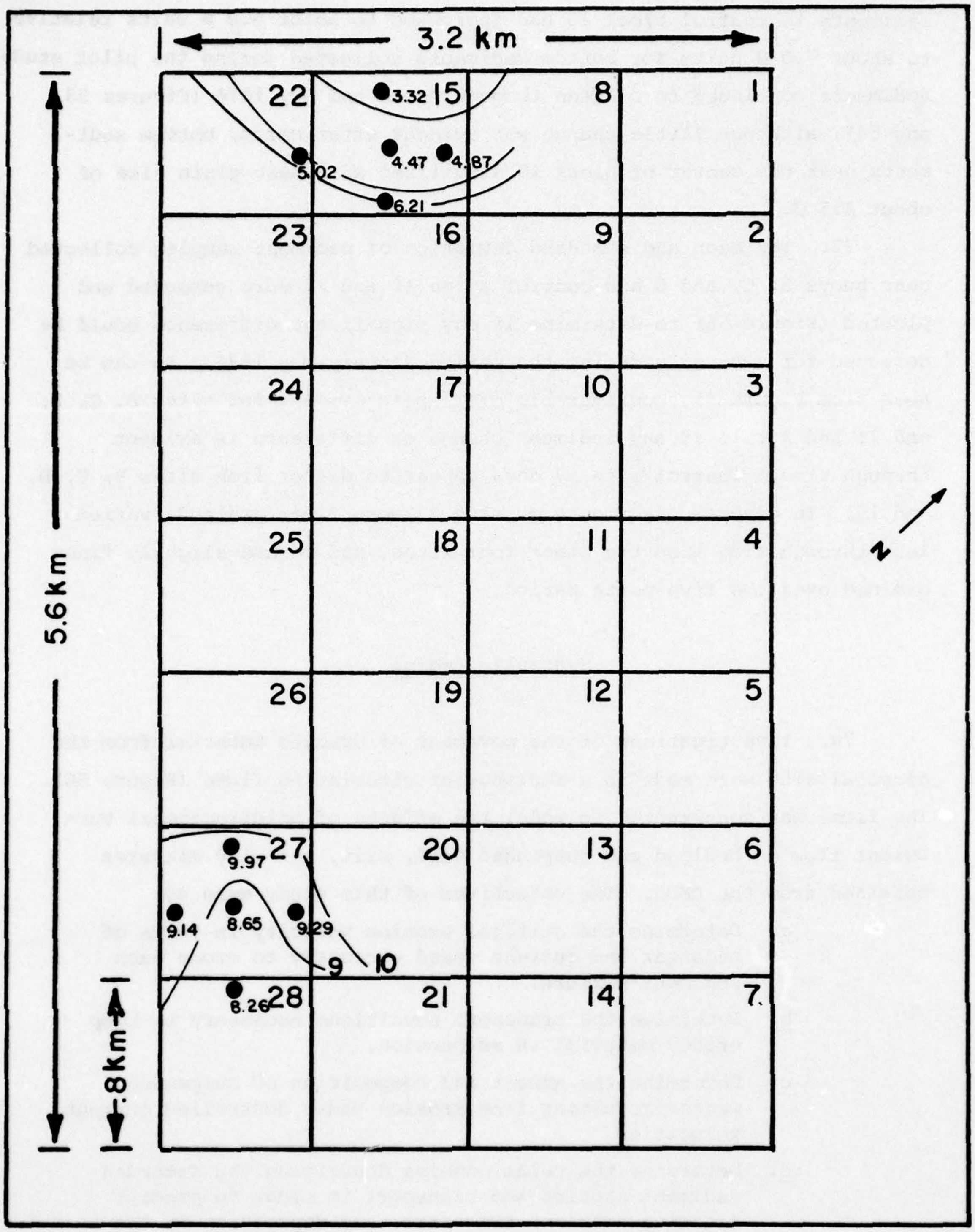


Figure 53. March mean sediment size (Ø units) of control site samples, blocks 15 and 27

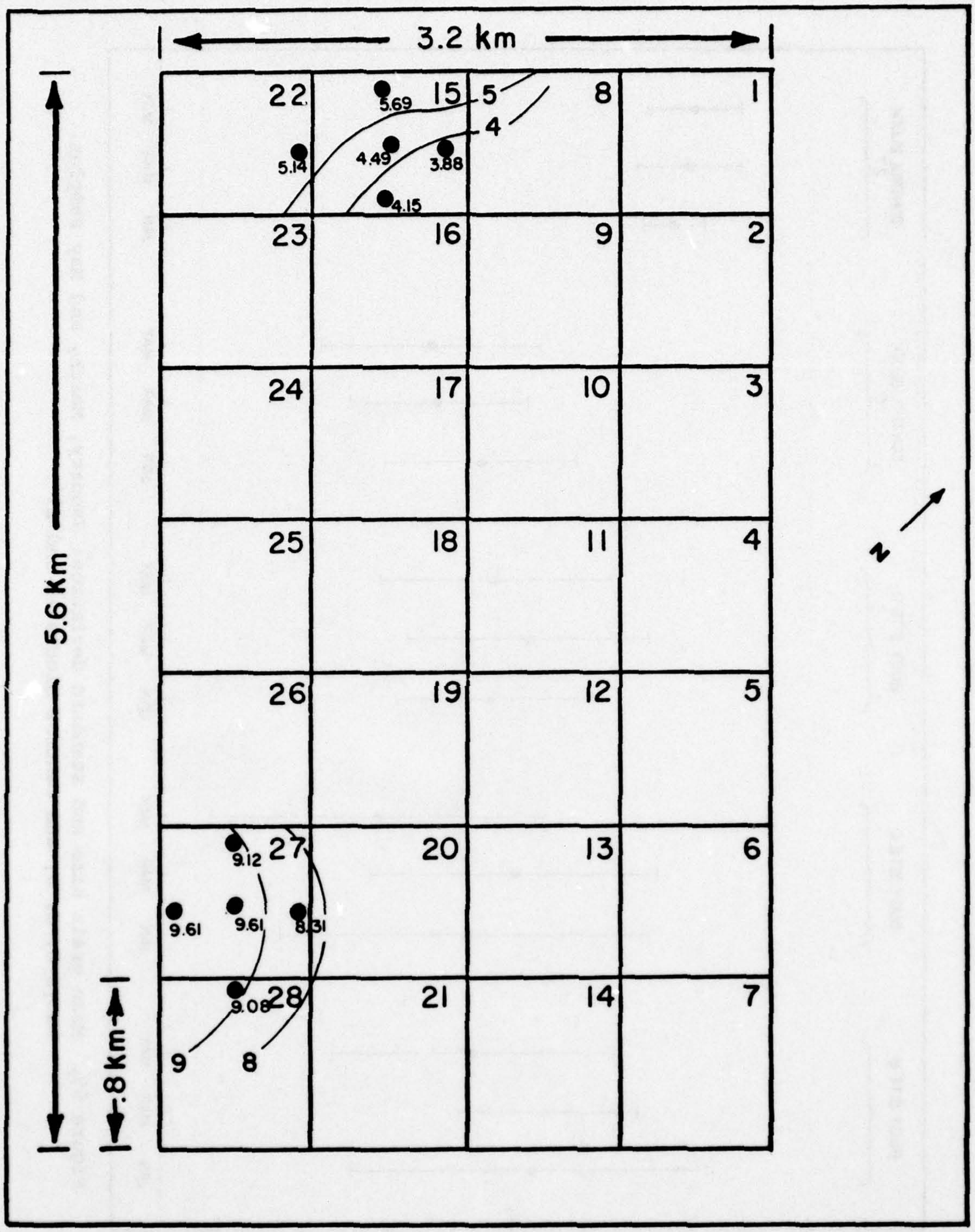


Figure 54. May mean sediment size (Ø units) of control site samples, blocks 15 and 27

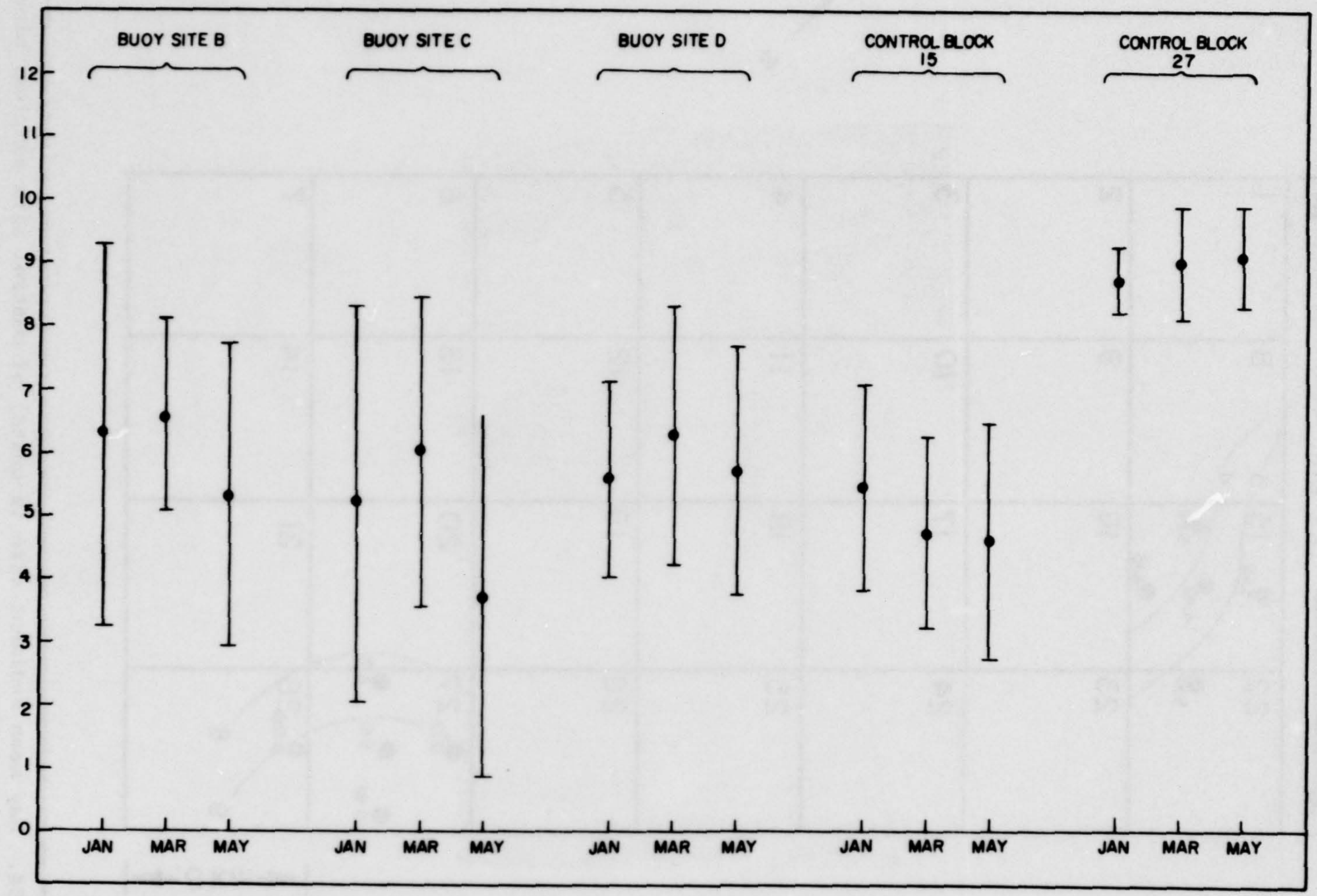


Figure 55. Mean grain size and standard deviation; January, March, and May samples, buoys B, C, D, and control blocks 15 and 27

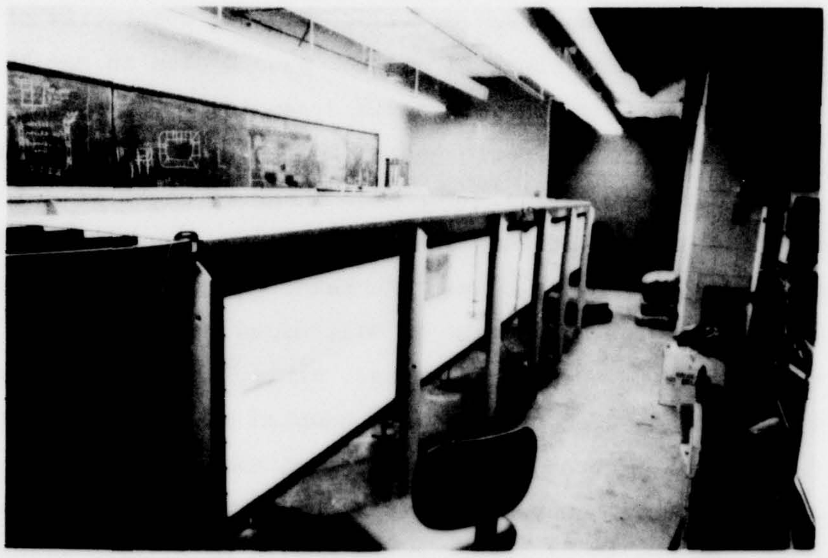


Figure 56. Side view of laboratory rectangular circulating flume (Moherek[23])

immediately adjacent to the offshore disposal site and attempt to determine the fate of the dredged materials.

79. To evaluate current activity in the DMDS, current data were obtained with a Bendix Q-15 current meter and two Braincon Savonius continuous recording meters. Vertical profile data using the Bendix meter were also taken at the buoy B, C, and D sites. Periodic malfunctioning of equipment prevented obtaining complete current data from the buoy C site.

80. A 100-kg sample of dredged material was obtained at the block 15 and buoy C sites during November 1975. Similar quantities of sediments were collected from block 27 and the buoy D site in May 1976. Geotechnical properties of collected field samples are presented in Table 6. Each analysis was performed on homogenized sediment samples prior to flume experimentation. The high shear strength of sediments collected at the buoy D site was attributed to the presence of the relatively consolidated Beaumont Clay. Moherek[23] determined that all sampled areas had a median grain size of silt-sized material, were poorly sorted, and exhibited variable skewness. Table 7 illustrates the grain-size distribution for dredged materials sampled at the four locations.

81. The mode of transport for each sediment sample was determined by monitoring the total suspended matter over time at given flow rates in the flume. Figure 57, for buoy C and D site materials, illustrates that the concentration of total suspended material (TSM) increased logarithmically during the initial few hours following current increases. This was attributed to resuspension of previously deposited turbidity flume sediments in the flume channel in addition to winnowing of material from the sediment mound itself.

82. The decrease in TSM that occurred in the 16 cm/sec buoy D experiment (Figure 57) indicated that suspended material was deposited. For all flow rates exceeding 16 cm/sec, a distinct textural coarsening of the sediment mound surface was observed, and the mound became armored by coarser material. Mass bedload transport was also noted for currents exceeding 23 cm/sec, measured at 30.5 cm above the bed.

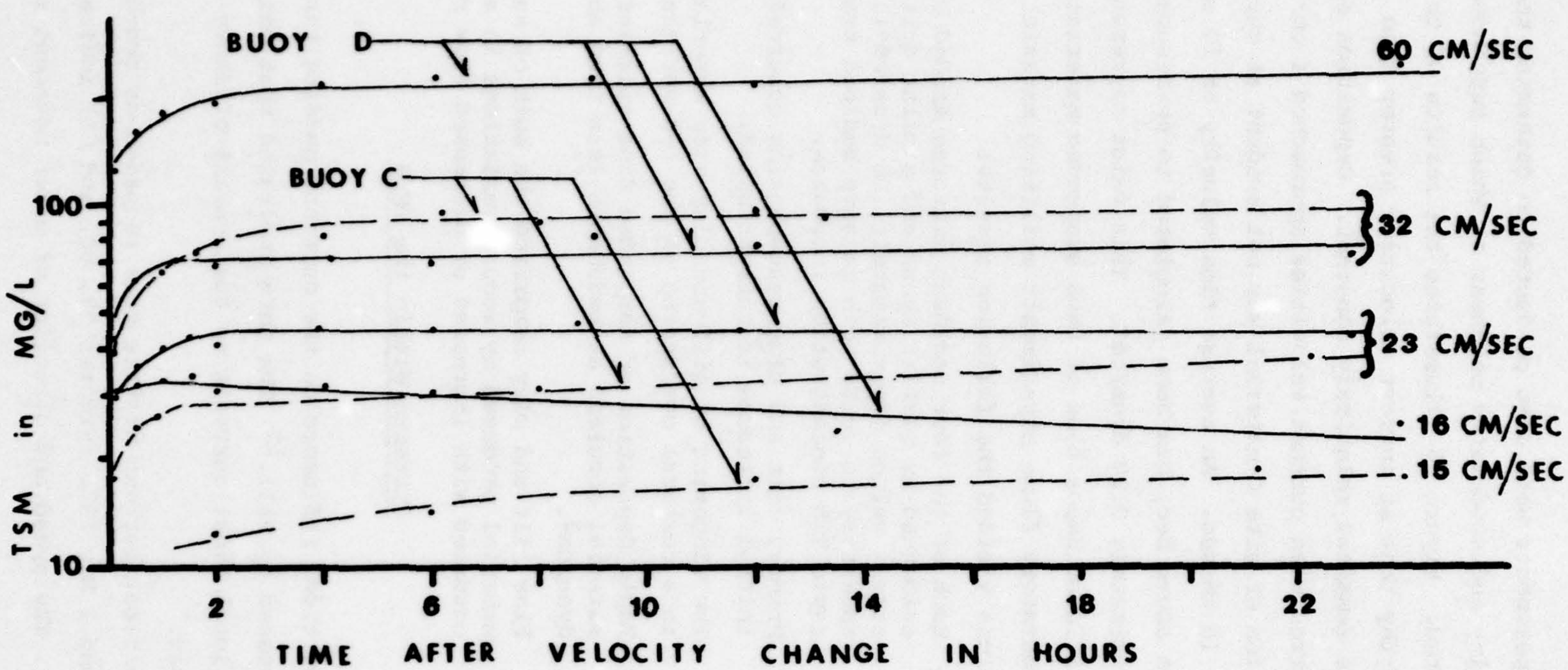


Figure 57. Selected dense bed erosional runs performed on buoy C and D sediments

83. Experiments were also conducted to determine the approximate current velocity and associated bedshear at which suspended sediments were redeposited. Figure 58 illustrates the results of this experiment. It was noteworthy that at current velocities greater than 10 cm/sec, TSM concentrations remained relatively constant. Deposition of buoy D material occurred when current velocities approached 4 cm/sec or less, while deposition of site C material was not evident at current velocities of over 10 cm/sec. An average flow velocity of 10 cm/sec, measured at 30 cm above bed, has been calculated to correspond to a bedshear of approximately 0.20 dyne/cm^2. This value represents the lower limit of significant deposition of DMDS suspended materials.

84. Laboratory flume experiments utilizing material obtained from the four stations yielded the following results:

a. Each of the four sediment mixtures eroded similarly as evidenced by similar scour and similar critical shear stress values (approximately 1.0 dyne/cm^2), which is necessary to cause both massive bedload transport and rapid TSM concentration increases.

b. Primary silt and clay resuspension occurred during initial increases in current speed.

c. The winnowing of silt-and clay-size material resulted in a textural coarsening of the bed surface.

d. Rapid deposition of suspended fine silt-and clay-size material occurred at bedshears less than about 0.2 dyne/cm^2.

e. Fine silt and clay comprised the bulk of suspended material produced by scour; variations in silt and clay occurred with increased or decreased flow rates.

Currents Within the DMDS

85. The tidal influence on the currents passing through the DMDS has been discussed by Hall.[19] The data indicated that only a partial dominance by local tidal currents on the overall offshore circulation pattern existed.

86. Vertical current profile data recorded at two-hr intervals at buoy C on 1 and 2 May 1976 (Figures 59, 60, and 61) indicated:

a. The speed and direction of water movement in the upper

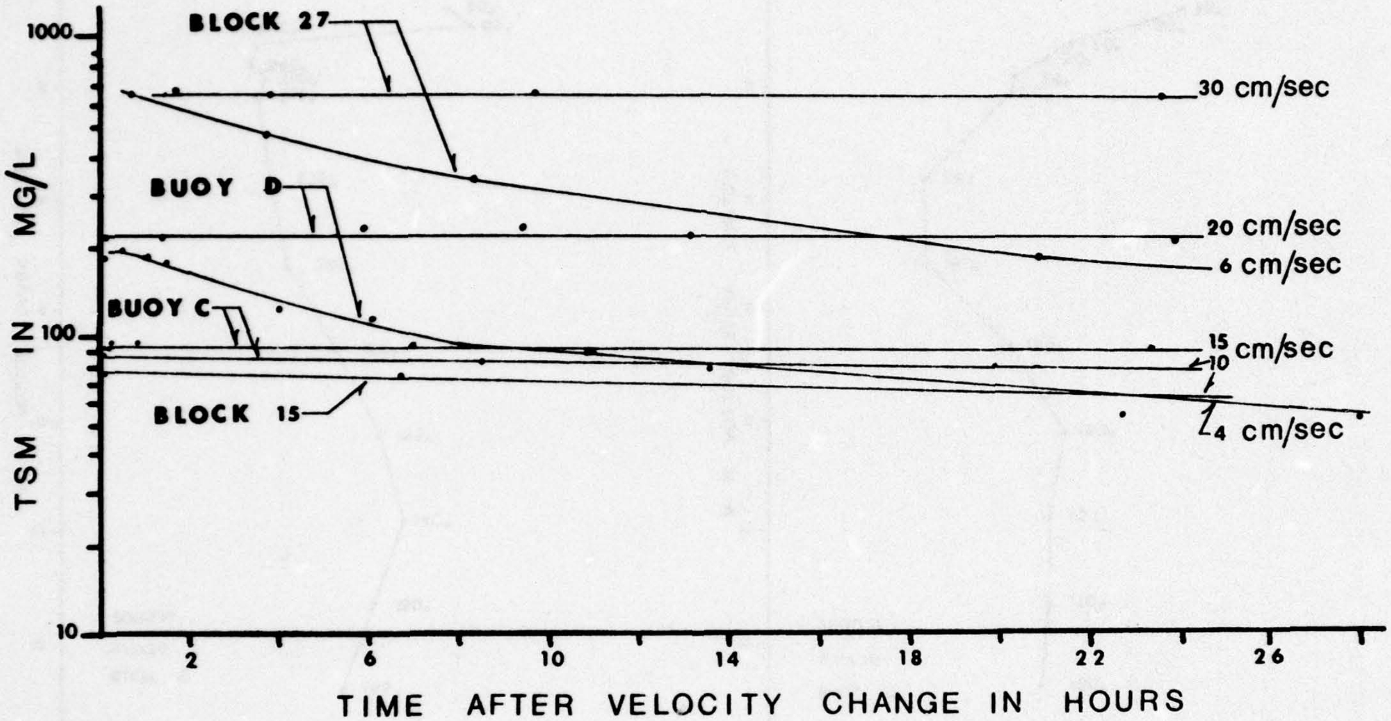


Figure 58. Depositional runs performed on each of the four sediment mixtures

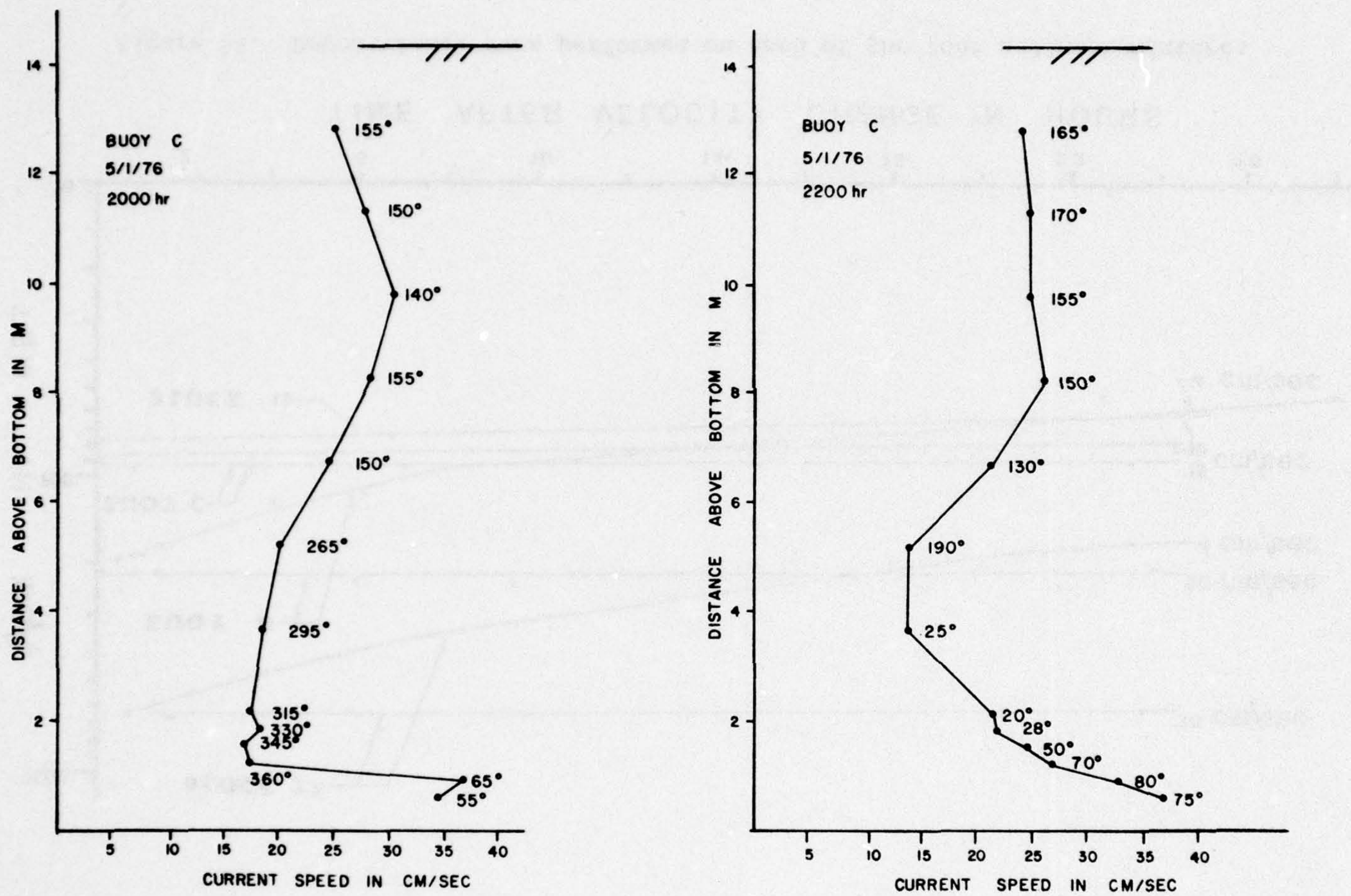


Figure 59. Two-hr interval vertical profiles obtained at buoy C, 1 May 1976 (current direction is in degrees magnetic north)

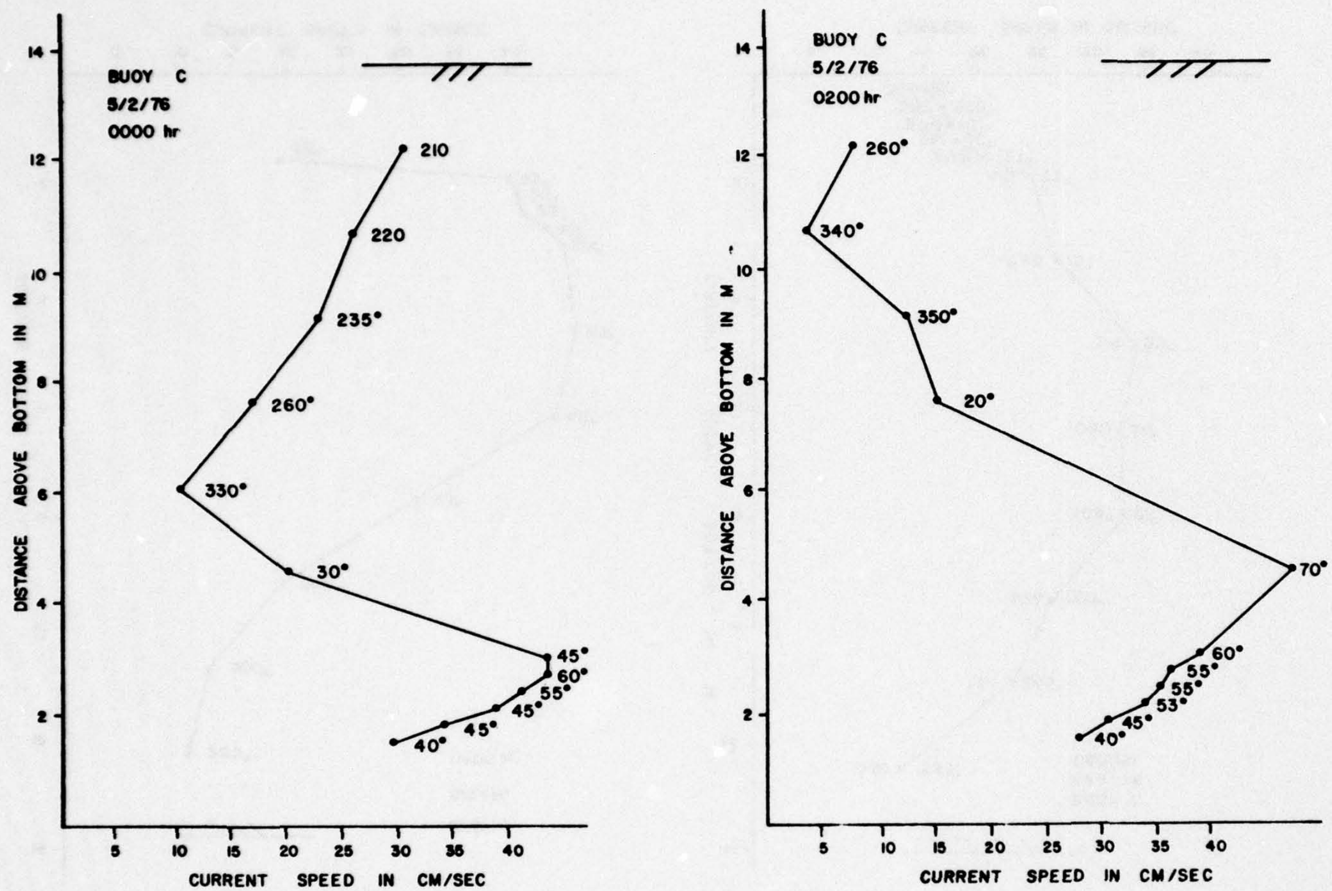


Figure 60. Two-hr interval vertical profiles obtained at buoy C, 2 May 1976 (current direction is in degrees magnetic north)

AD-A050 812 MOODY COLL OF MARINE SCIENCES AND MARITIME RESOURCES --ETC F/G 13/2
AQUATIC DISPOSAL FIELD INVESTIGATIONS, GALVESTON, TEXAS, OFFSHO--ETC(U)
DEC 77 E L ESTES, R J SCRUDATO DACW64-75-C-0069

UNCLASSIFIED WES-TR-D-77-20 NL

2 OF 2
AD
A050 812

END
DATE
FILMED
4-78
DDC

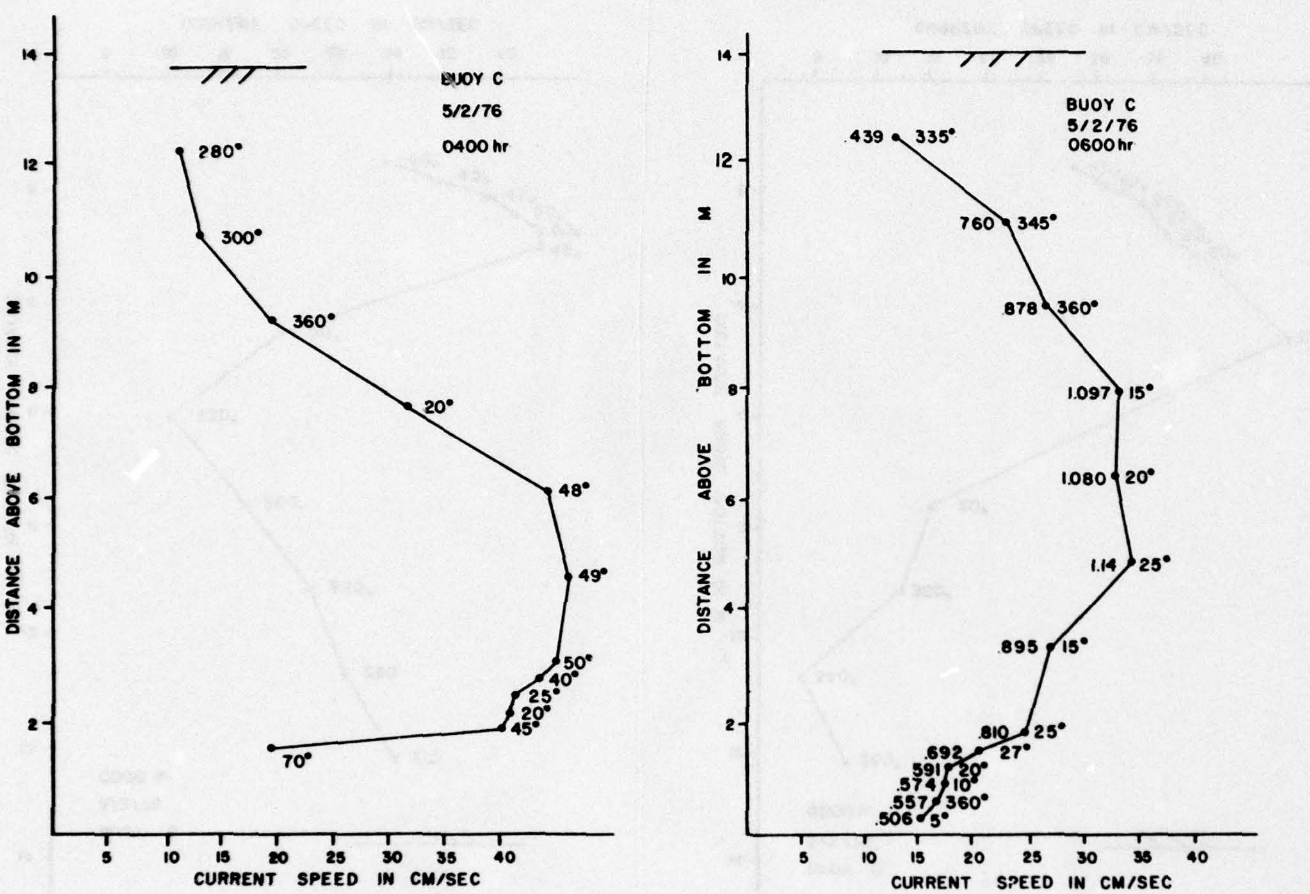


Figure 61. Two-hr interval vertical profiles obtained at buoy C, 2 May 1976 (current direction is in degrees magnetic north)

portion of the water mass coincided with Galveston offshore tidal currents.

b. A northeasterly directed bottom flow occurred throughout most of the observation period.

c. A shear layer existed between the near bottom and upper water column currents, with flow reversals possible near the bed.

87. In order to compare current velocity fluctuations during a tidal cycle, a plot of velocity at various depths versus time (Figure 62) is presented from data collected at buoy C, 1 May through 2 May 1976. These data indicated that high speed surface ebb currents were coupled with low speed ebb flows lower in the water column, and flood-directed currents exhibited greater velocities at the sea floor than at the surface.[23]

88. Typical velocity profiles obtained near buoys B and D are presented in Figures 63 and 64. The profile from buoy D exhibited current velocities and directions concurrent with an ebb-directed surface flow and flood-directed bottom flow. This apparent flow reversal demonstrated the spatial and temporal dissimilarities between the upper and lower water column currents at the southern margin of the DMDS. In contrast, profiles taken at the buoy B site suggest uniformity in current direction throughout the water column.

89. The total current regime exhibited by the buoy B, C, and D velocity profiles is consistent with the general circulation patterns described by Hall.[19] Figure 65 illustrates the flow pattern developed during flood tide while Figure 66 illustrates the ebb-flow circulation pattern.

90. To evaluate bottom circulation active at the DMDS, progressive vector diagrams were prepared from continuous bottom current data recorded at the buoy B and D sites. These represent a plot of the resultant vectors and portray a trajectory with spatial dimensions. True water mass movement is not actually illustrated by the vector path and these diagrams are primarily of qualitative value in assessing net bottom water movement.

91. Figure 67 illustrates a progressive vector diagram plotted

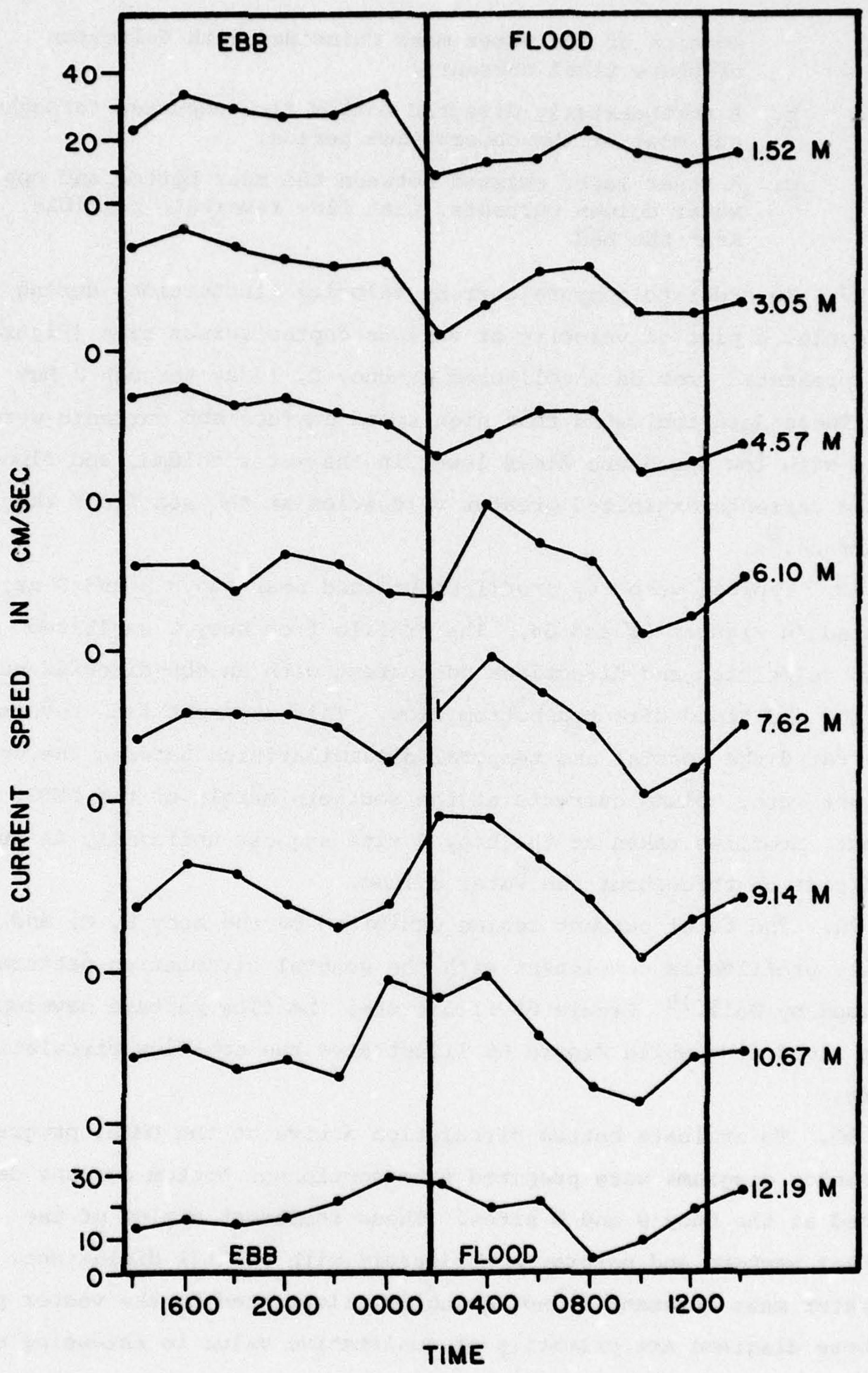


Figure 62. Flow velocity at various depths versus time for the period 1400 hr 1 May to 1400 hr 2 May 1976 at buoy C

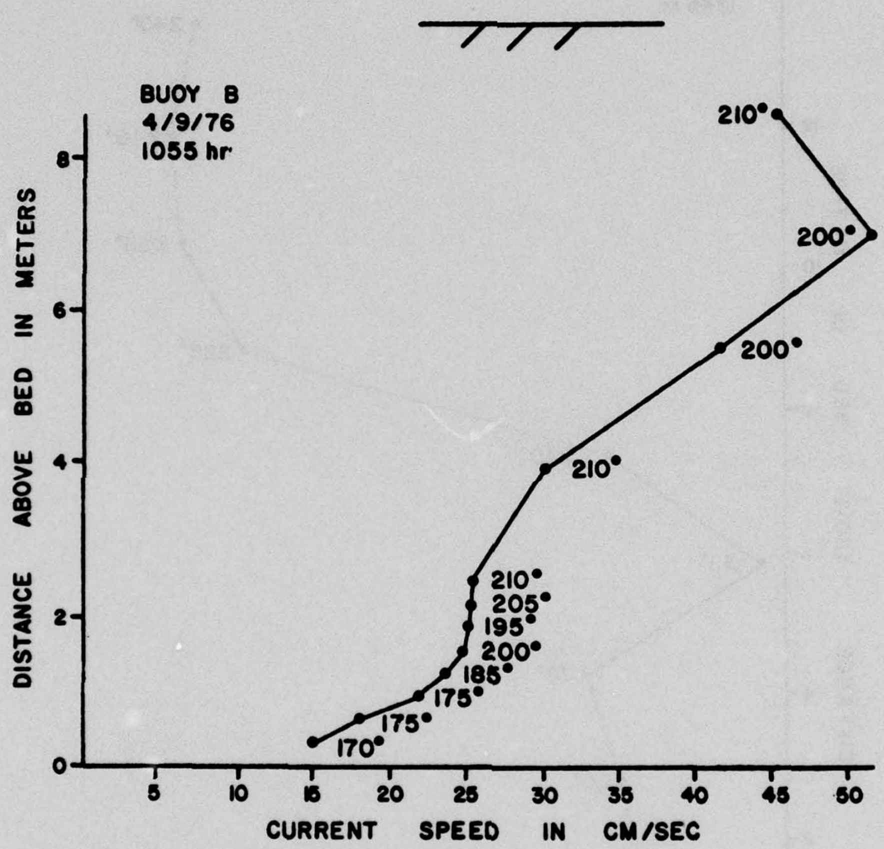


Figure 63. Velocity profile obtained at buoy B, 1055 hr, 9 April 1976 (current direction is in degrees magnetic north)

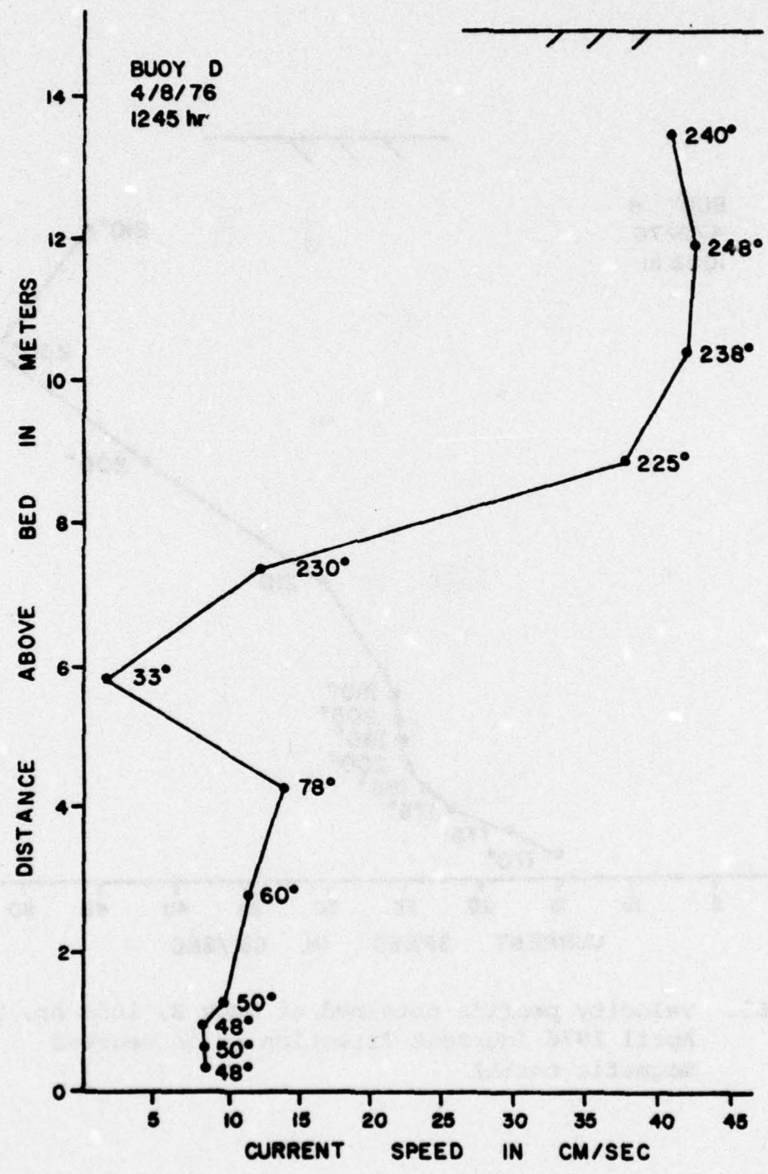


Figure 64. Velocity profile obtained at buoy D, 1245 hr, 8 April 1976 (current direction is in degrees magnetic north)

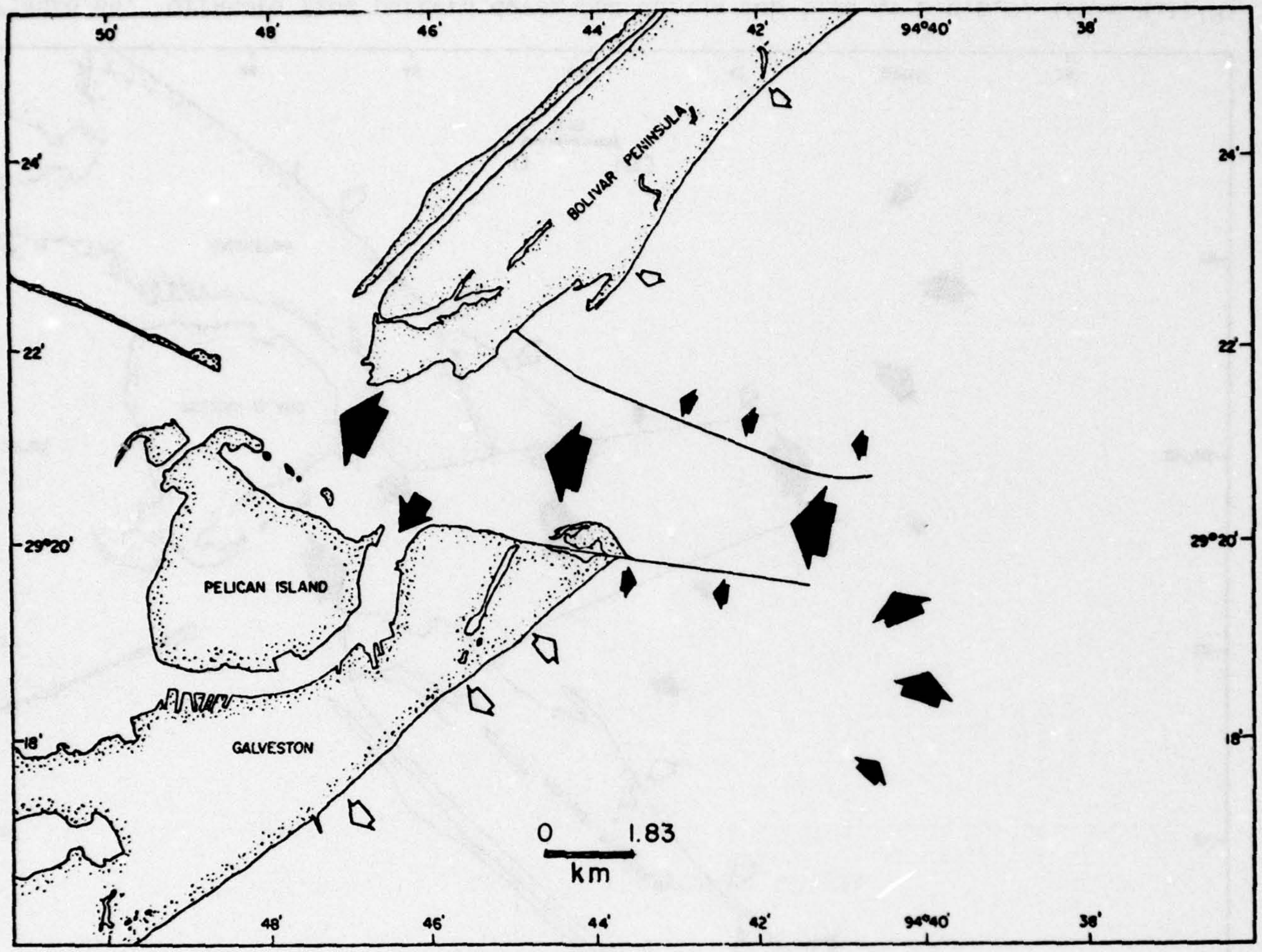


Figure 65. Offshore flow pattern developed during flood tide at B.G.E.C. (from Hall[19])

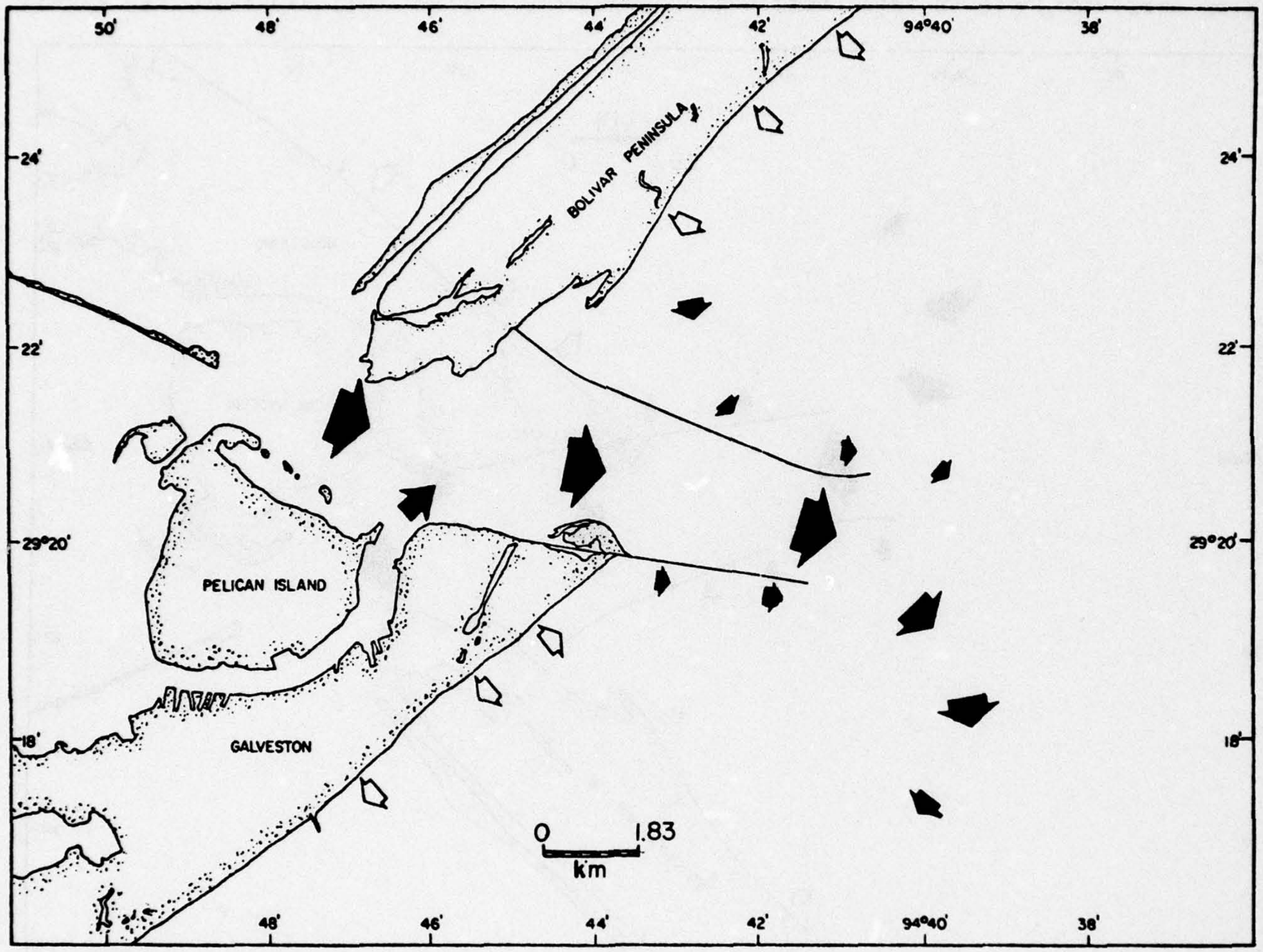


Figure 66. Offshore flow pattern developed during ebb tide at B.G.E.C. (from Hall[19])

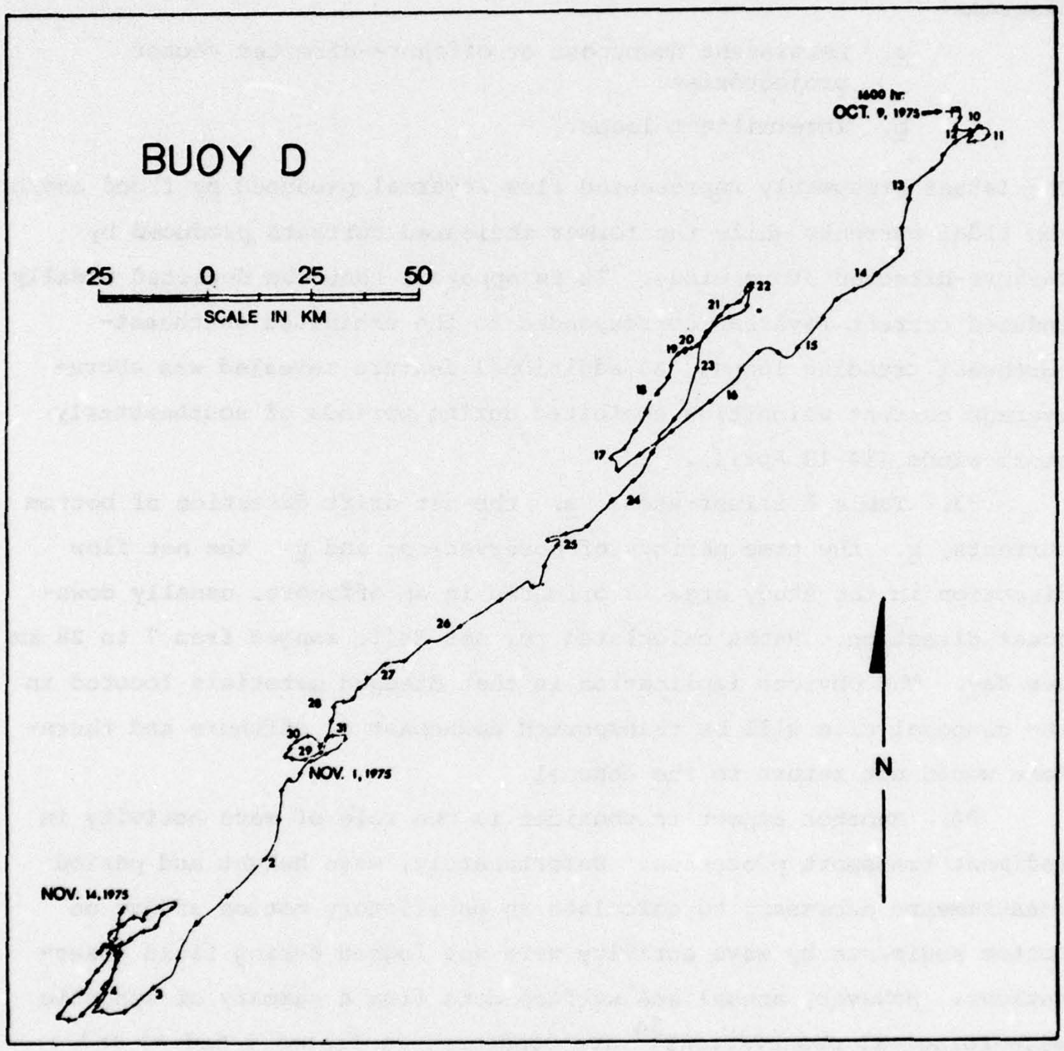


Figure 67. Progressive vector diagram for 9 October through 14 November 1975 at buoy D site

from 15-min interval current velocity measurements recorded 1.0 m off bottom at the buoy D site. Each plus sign (+) marks the start of a six-hr period. Based on this information, a net drift of 260 km toward the southwest is apparent.[19]

92. Figures 68-71 illustrate progressive vector diagrams constructed from current readings recorded at buoys B and D during March and April 1976. Two significant current features are evident from these diagrams:

- a. Persistent downcoast or offshore-directed vector projectories.
- b. Intermittent loops.

The latter presumably represented flow reversal produced by flood and/or ebb tidal currents while the former indicated currents produced by onshore-directed storm winds. It is apparent that the depicted tidally induced current reversal corresponded to the exhibited southeast-northwest trending loops. An additional feature revealed was above-average current velocities exhibited during periods of southeasterly storm winds (14-19 April).

93. Table 8 illustrates: a. the net drift direction of bottom currents; b. the time periods of observation; and c. the net flow direction in the study area is oriented in an offshore, usually downcoast direction. Rates calculated for net drift ranged from 7 to 28 km per day. The obvious implication is that dredged materials located in the disposal site will be transported downcoast or offshore and therefore would not return to the channel.

94. Another aspect to consider is the role of wave activity in sediment transport processes. Unfortunately, wave height and period measurements necessary to calculate an oscillatory motion effect on bottom sediments by wave activity were not logged during field observations. However, annual sea surface data from a summary of synoptic meteorological observations[24] are condensed in Tables 9 and 10 and Appendix A'. Three important findings were evident from these summaries:

- a. Prevailing wind directions for offshore Galveston, in order of decreasing frequency, were southeast, east, and south.

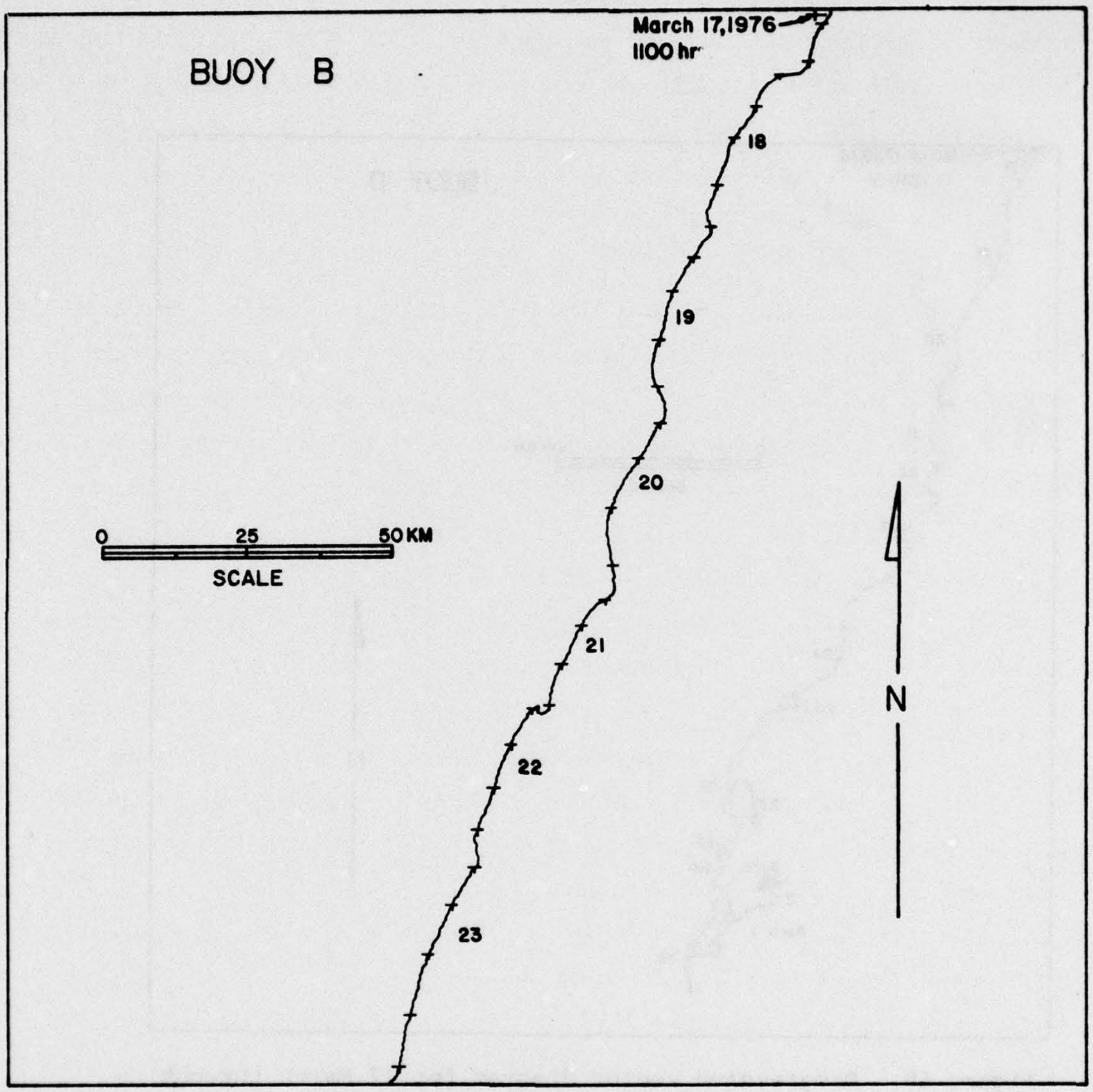


Figure 68. Progressive vector diagram for 17 March through 23 March 1976 at buoy B

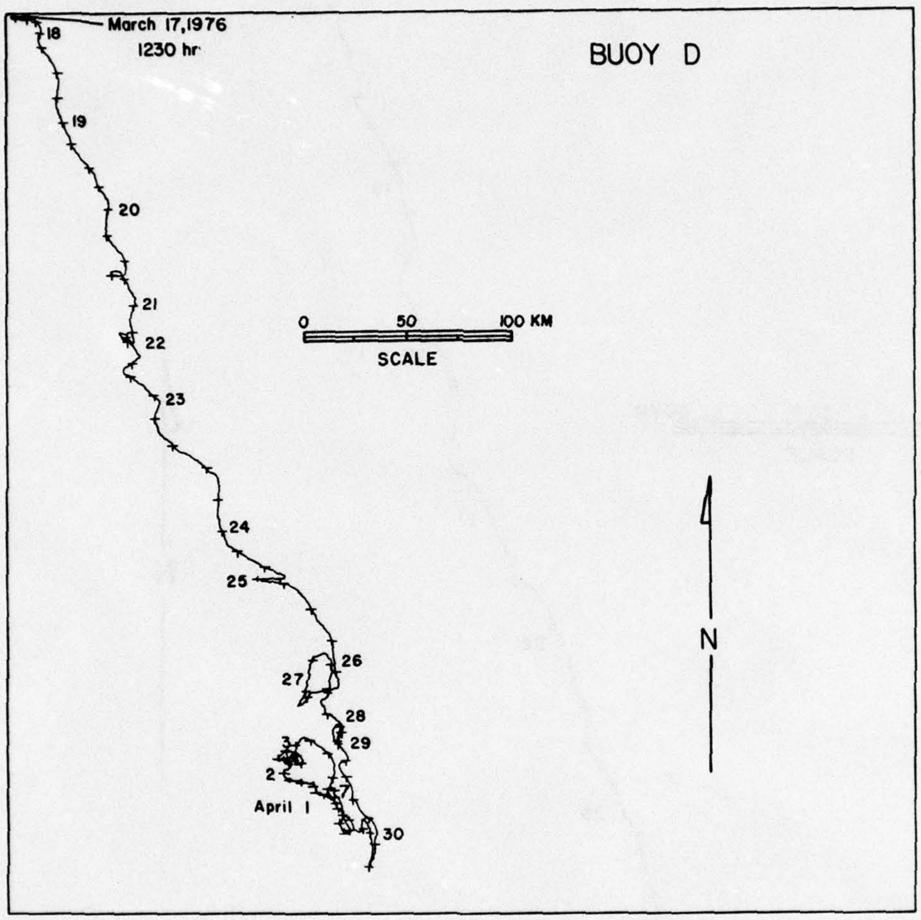


Figure 69. Progressive vector diagram for 17 March through 7 April 1976 at buoy D

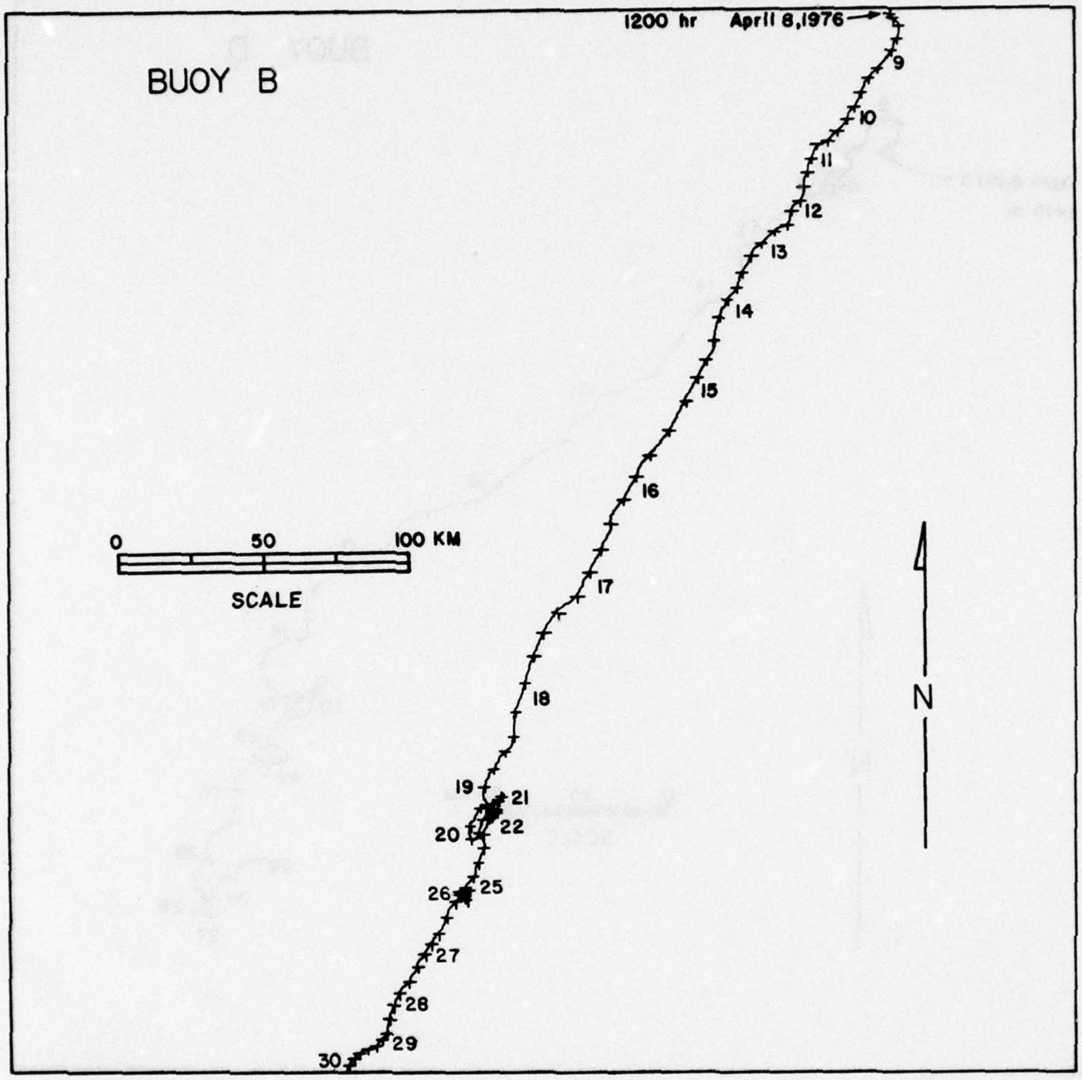


Figure 70. Progressive vector diagram for 8 April through 30 April 1976 at buoy B

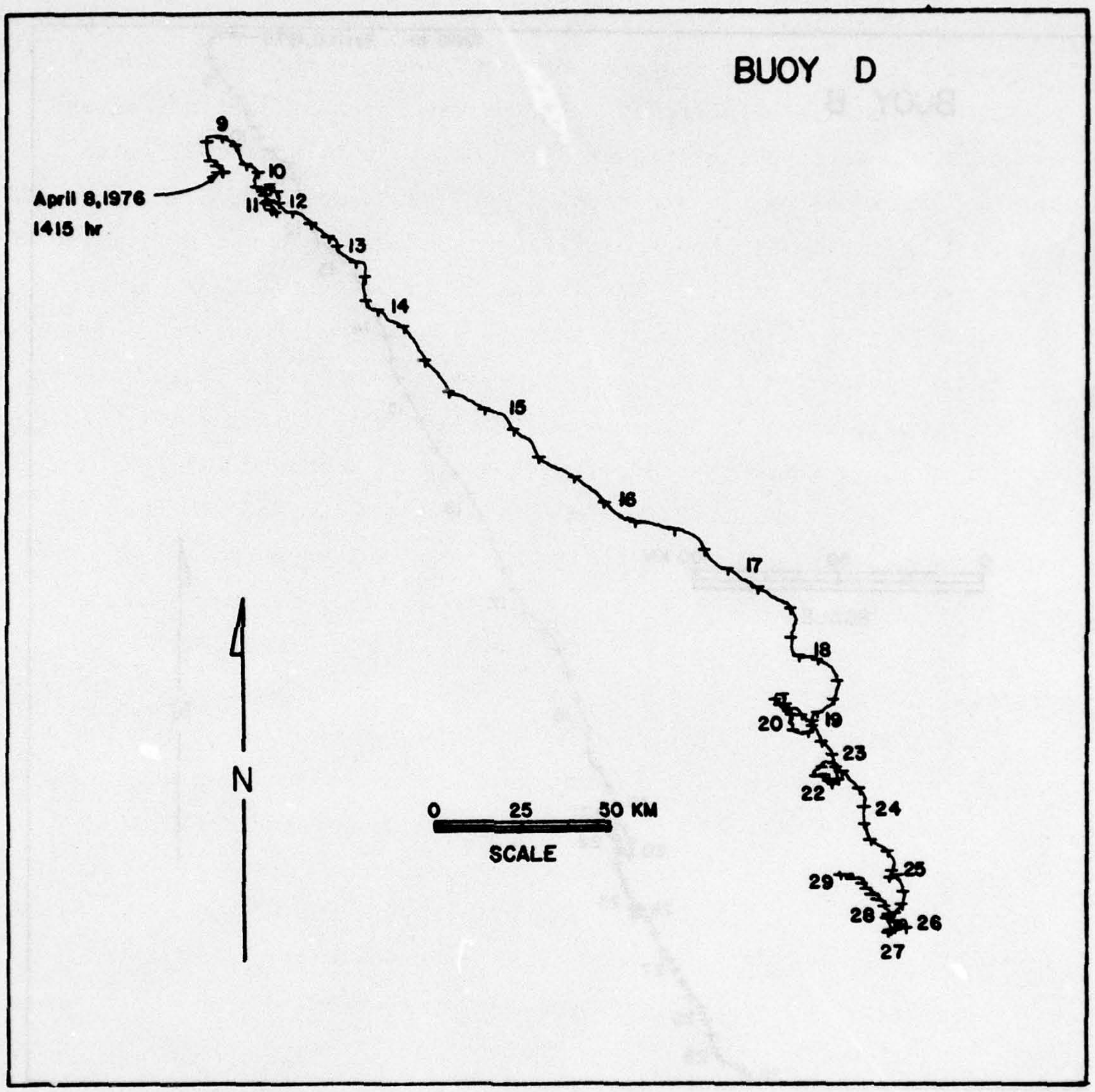


Figure 71. Progressive vector diagram for 8 April to 29 April 1976 at buoy D

b. Wind speeds ranging from 1.5 to 10.8 m/sec generated sea waves 0.25 to 1.75 m in height.

c. Surface waves ranging in height from 0.25 to 1.75 m usually had wave periods less than 6.0 sec. However, swells exceeding 1.25 m in amplitude have occasionally been recorded with periods ranging from 6.0 to 9.0 sec.

95. The significance of these data in assessment of the effect of wave activity on bottom sediment movement was revealed by a plot of oscillatory bottom velocity (U_m) versus wave period (sec) for an average 14.0 m water depth (Figure 72). As shown in Figure 72, wave periods in excess of 5.0 sec coupled with wave heights greater than 0.75 m would theoretically induce oscillatory bottom speed water movement at rates exceeding 10 cm/sec. The frequency of wave height versus wave period data (Table 10) suggests that such wave amplitudes and periods can occur up to 30 percent of the time in the DMDS, and if these near-bottom oscillatory motions are superimposed on an existing 10-20 m/sec bottom current, the threshold of silt and clay movement will probably be exceeded. Continuous near-bottom oscillatory motion may prevent deposition of suspended materials if the resultant bedshear exceeds the threshold shear (0.2 dyne/cm^2). It is therefore concluded that sea state conditions in the DMDS significantly affect local near-bottom sediment transport processes.

96. Figure 73 illustrates wind roses and net bottom current drift vectors for the offshore Galveston area. This information was based on a data-collection period of 31 days at the buoy B site and 81 days at the buoy D site and was not extensive enough in duration to establish annual net drift direction with any statistical confidence.[23]

97. Figures 74 through 78 illustrate cumulative curves of the current velocity distribution for portions of the study period. These data indicated that the median velocities at the buoy B site ranged from 22 to 35 cm/sec while those for the buoy D site were slightly lower, ranging from 18 to 22 cm/sec.

98. The frequency of the current speeds for each observation period was examined in order to determine the time during which critical erosion velocities were exceeded (Table 11). In addition, transport and

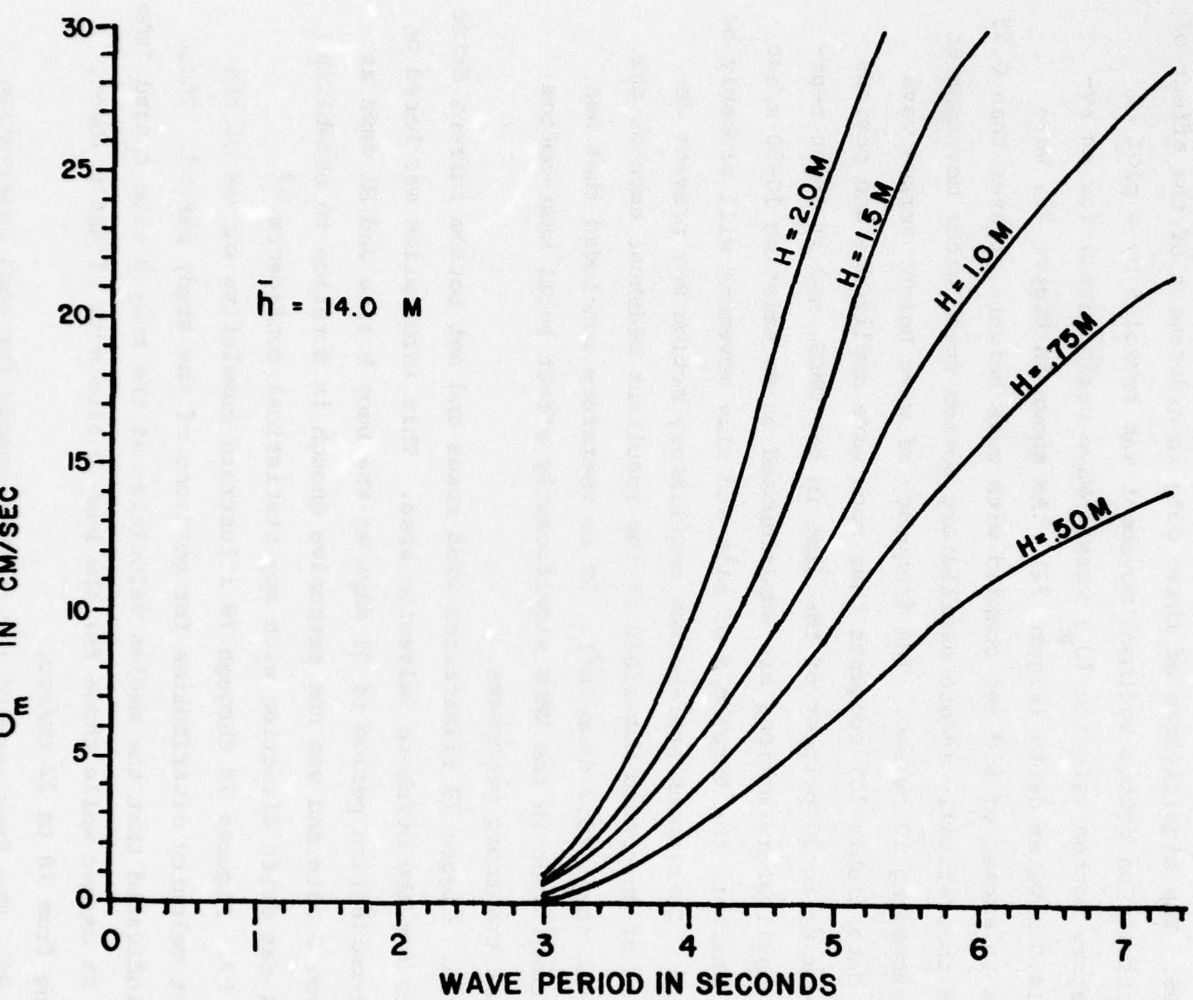


Figure 72. Relationship between wave period and oscillatory bottom velocity (U_m) for an average 14-m water depth; H = wave height

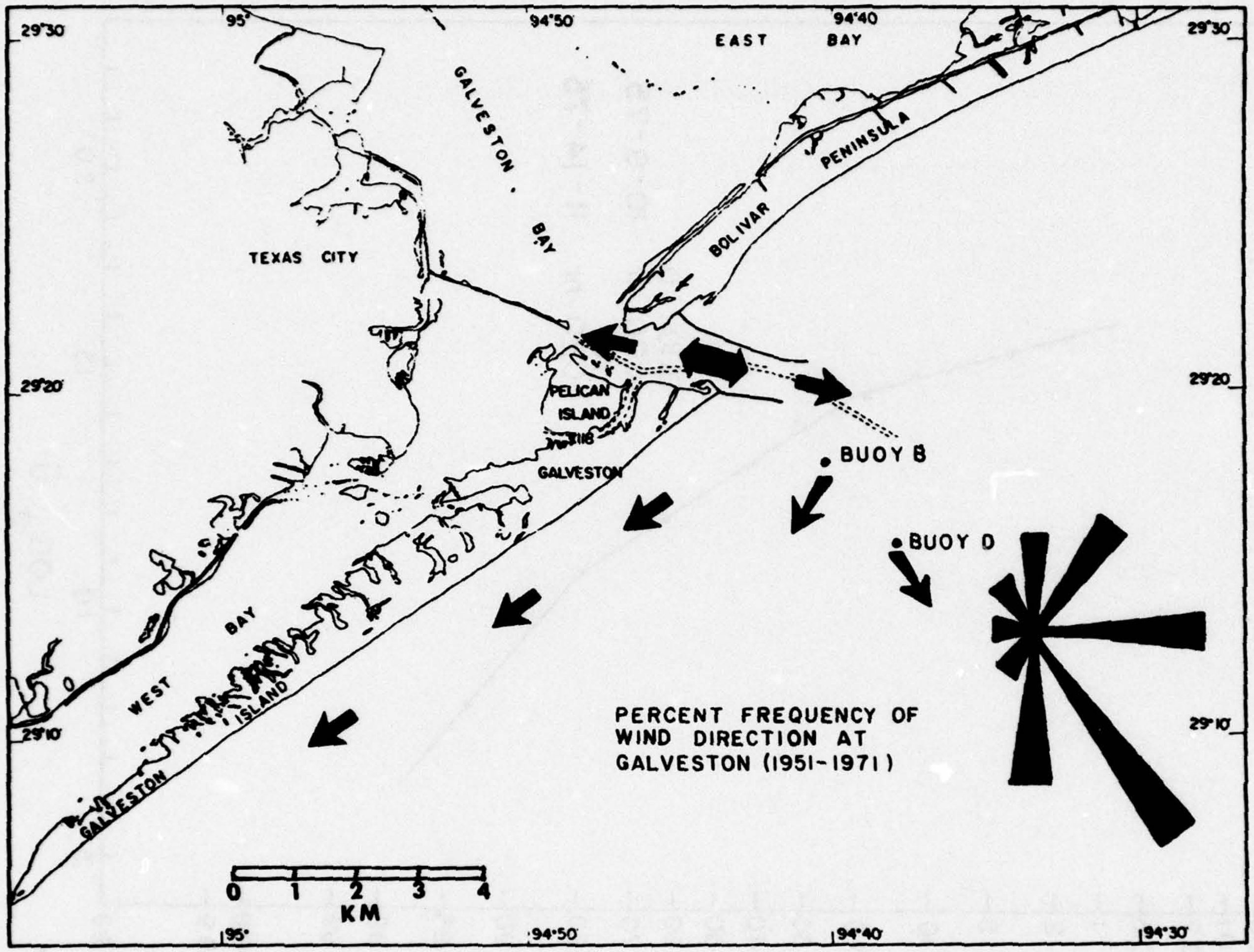


Figure 73. Wind rose and net bottom drift vectors for offshore Galveston

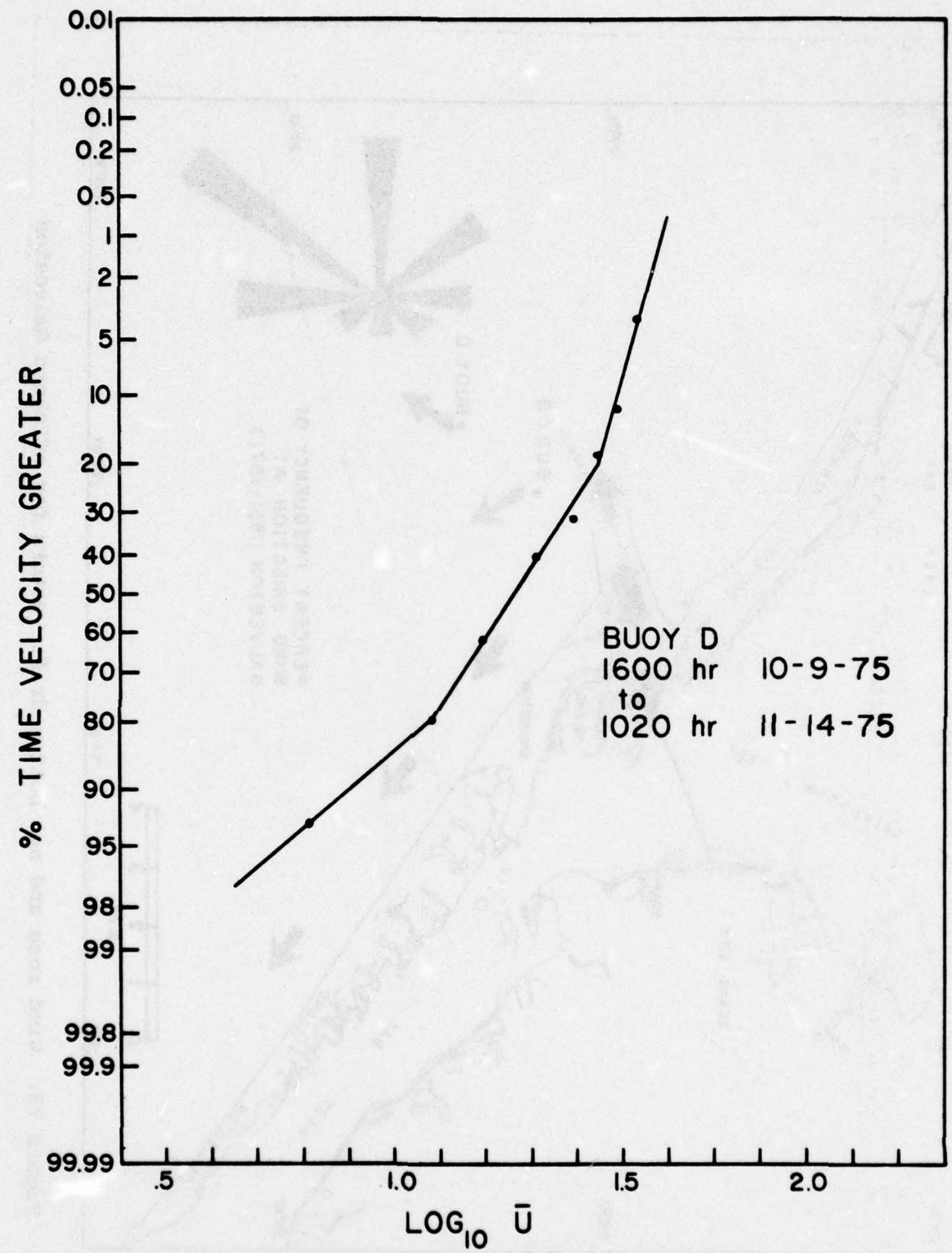


Figure 74. Cumulative curve of the current velocity distribution for 9 October to 14 November 1975 at buoy D, modified from Hall[19] ($\bar{U}$ = average current speed measured one m above bed)

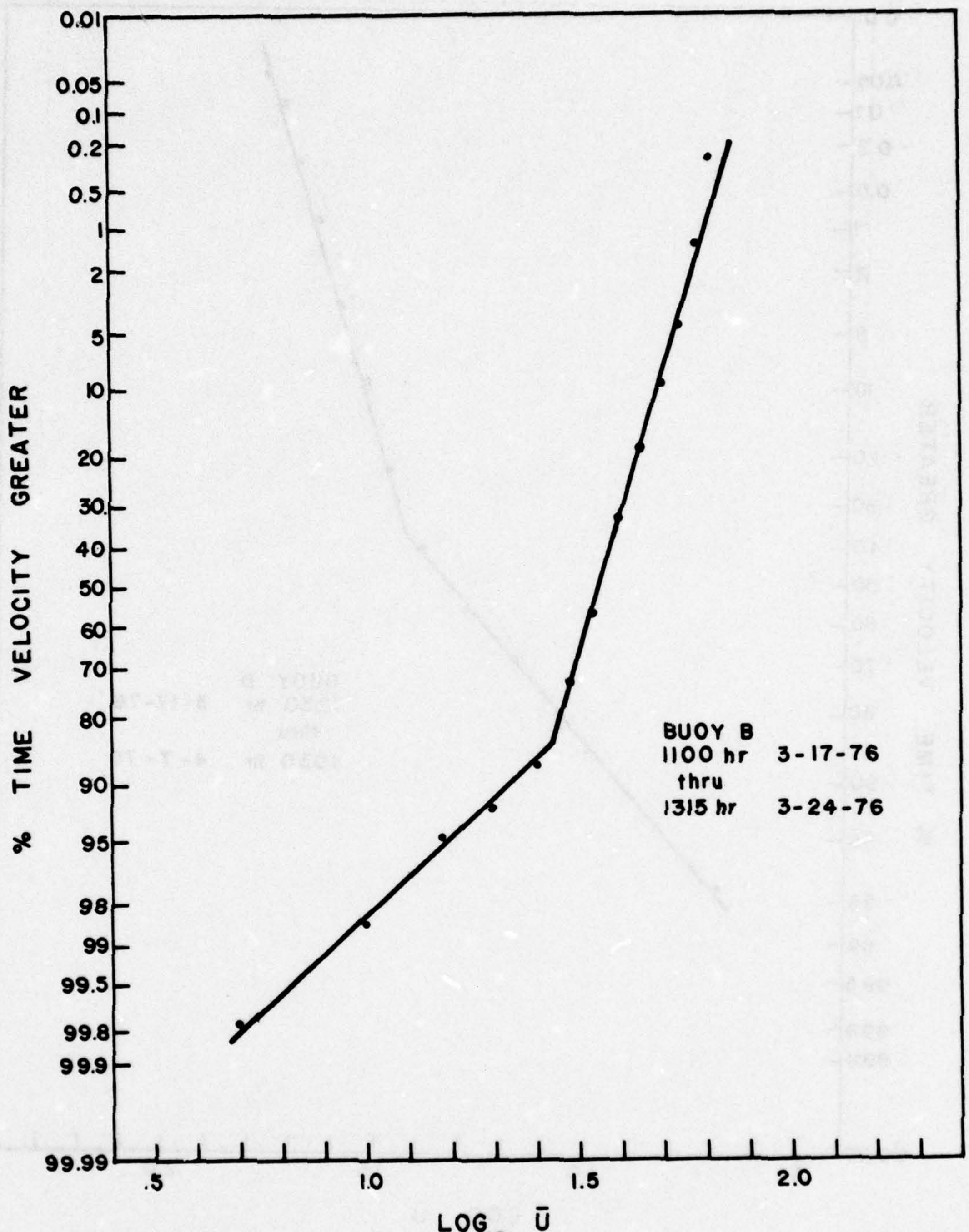


Figure 75. Cumulative curve of the current velocity distribution for 17 March to 24 March 1976 at buoy B (Ū = average current speed measured one m above bed)

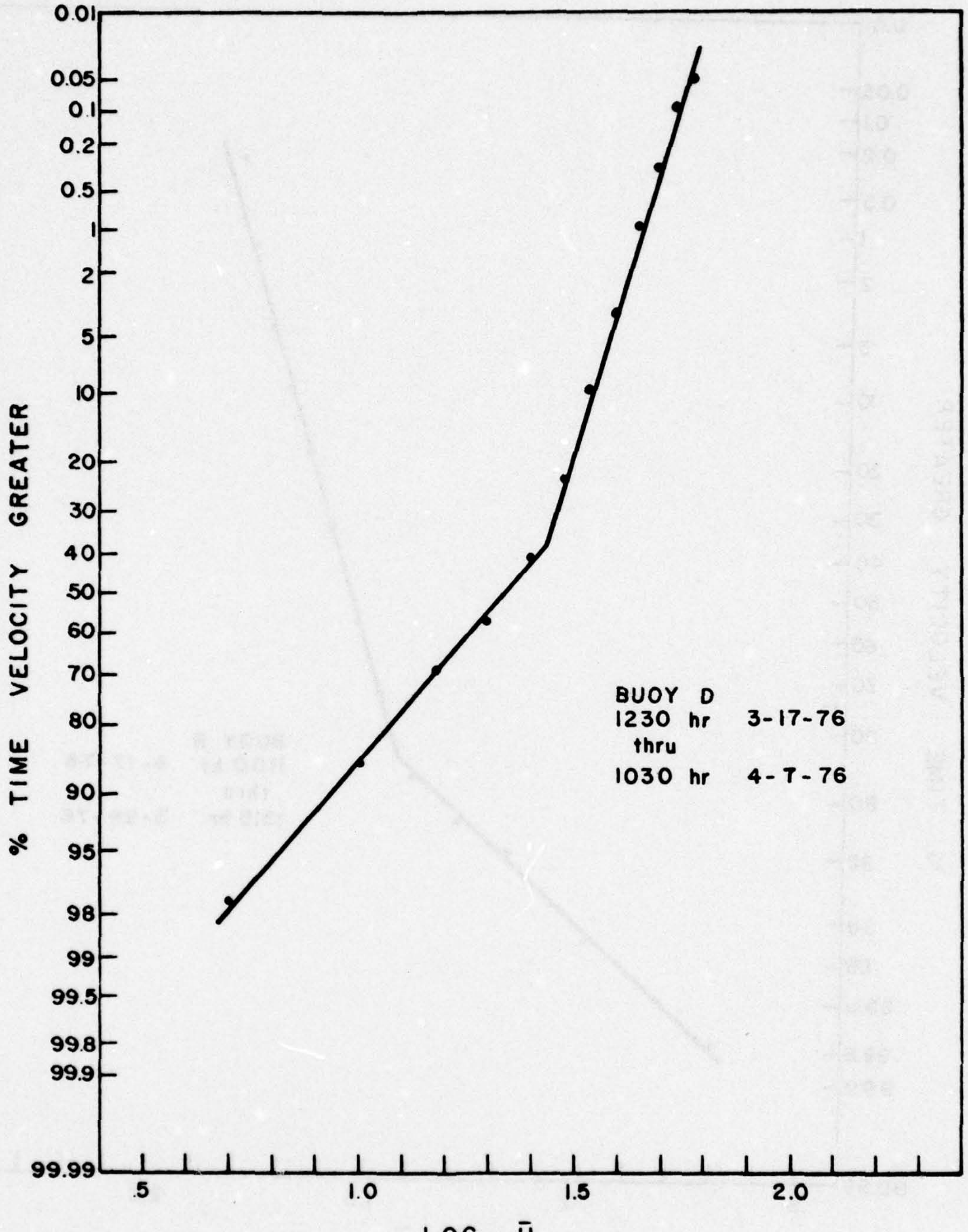


Figure 76. Cumulative curve of the current velocity distribution for 17 March to 7 April 1976 at buoy D ($\bar{U}$ = average current speed measured one m above bed)

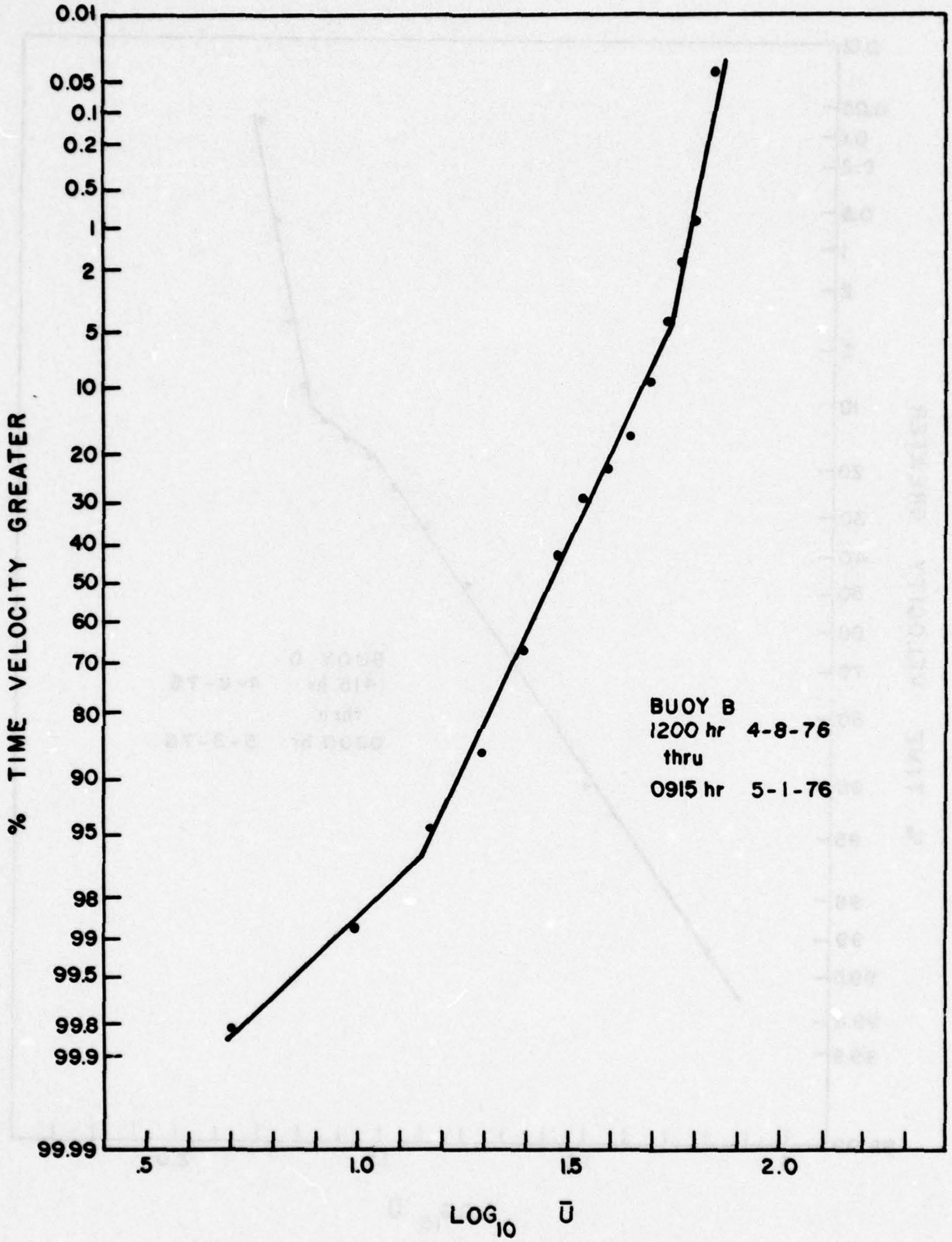


Figure 77. Cumulative curve of the current velocity distribution for 8 April to 1 May 1976 at buoy B ($\bar{U}$ = average current speed measured one m above bed)

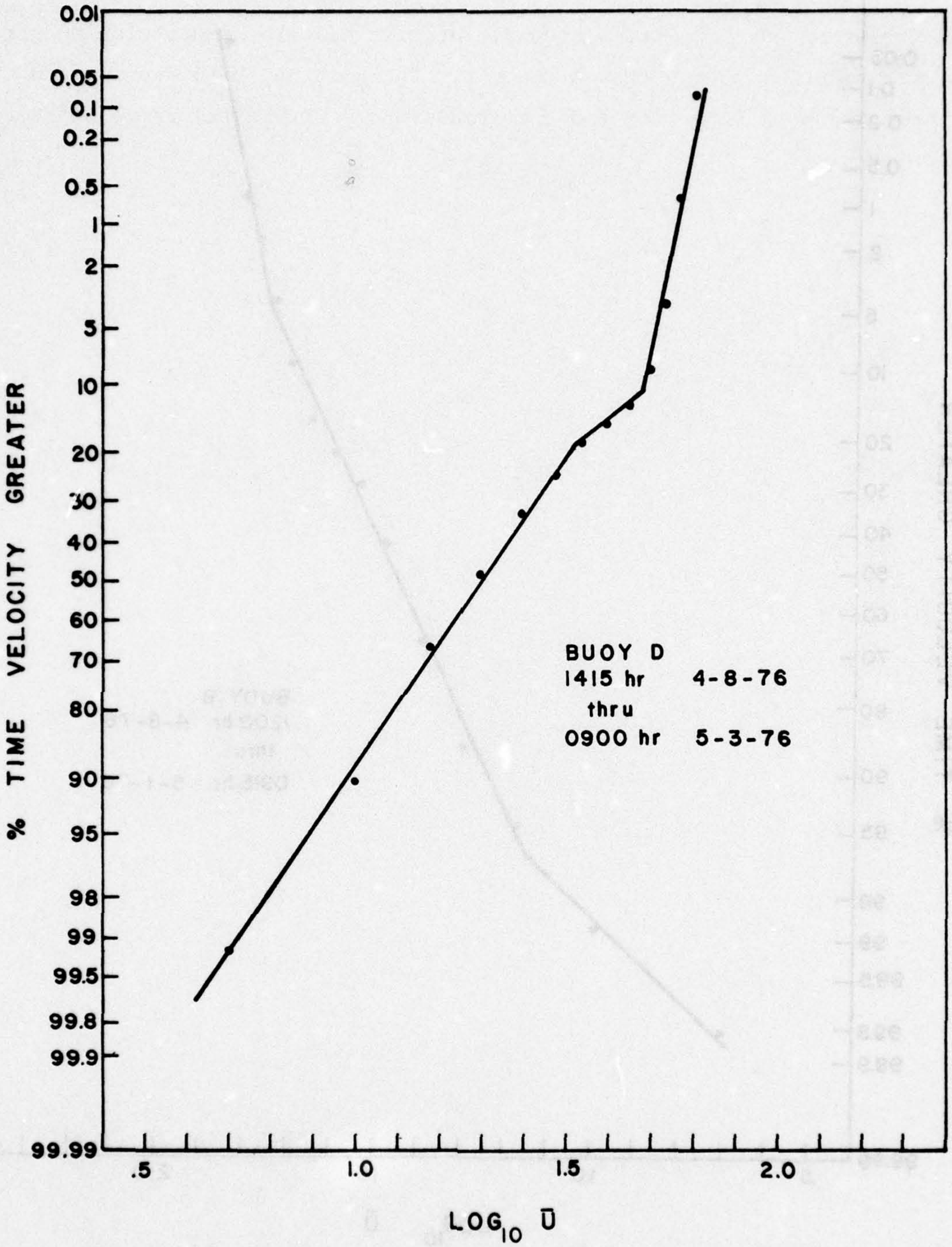


Figure 78. Cumulative curve of the current velocity distribution for 8 April to 3 May 1976 at buoy D ($\bar{U}$ = average current speed measured one m above bed)

erosion times were also calculated. It is apparent that bedload erosion could occur more frequently at the buoys B and C sites. Similarly, current speeds permitting significant silt and clay deposition occurred more often at buoy D than at buoy B. In addition, both erosion and deposition of fine silt and clay could occur within the range of these velocities.[23]

PART IV: INTERPRETATION OF RESULTS

99. This section discusses the predisposal and postdisposal characteristics of the DMDS and attempts to integrate the various study phases employed to gain an understanding of the fate of disposed dredged materials through time. Comparisons are made between sediment and carbonate concentrations and bathymetric differences evident from data collected during the pilot and postdisposal phases of the study. The differences determined are discussed in light of the hydraulic regime within the DMDS. Estimates of velocities required to redistribute DMDS bottom sediments are based on comparisons between flume experiment studies and on-site current meter data.

Buoy B Site

100. Sediment data collected in proximity to buoy B indicated considerable changes occurred throughout the study period. The mean size of sediment collected during the pilot study phase was about 5.5 Ø (Figure 18). *After disposal, the* sediment at the disposal site had become significantly coarser grained by January (2.17 Ø). After January, the sediments became finer grained. Winnowing was most evident near the buoy; the sediment became increasingly finer grained away from the buoy sampling site with the exception of the coarser grained sediment identified to the northeast of the disposal site, where a tongue of sand extended into the DMDS from the northeast.

101. From January to May 1976, bottom sediments in proximity to the disposal mound crest became finer grained (2.17-4.2 Ø). By May, these sediments had become progressively coarser grained toward the south, whereas a significant decrease in mean grain size was evident toward the northeast. It appears from these data that by May, fine-grained sediment was blanketing coarser grained sediments located northeast of the disposal mound.

102. Carbonate data from the buoy B site reflected the general decrease in mean grain size nearest the disposal mound crest. During

January, carbonate concentrations were about 33 percent; by May these concentrations had decreased to about 2 percent. A small decrease was also evident northeast of the disposal mound where carbonate concentrations decreased from 5 percent during January to about 2 percent by May. This again suggested that the sediments became finer grained toward the northeast over the five-month period (see Figures 40-42).

103. The sediment and carbonate data indicated that bottom sediments at the buoy B site were redistributed during the period January-May 1976. Bathymetric survey comparisons at the buoy B site suggested that as much as 337,000 m^3 were eroded from the mound from the time of dredged material disposal (August-September 1975, and February-March 1976) until June 1976. Limited current data from the buoy B site indicated net drift toward the south-southwest.

104. Although bottom current data were collected over limited periods (3/17/76-3/24/76 and 4/8/76-5/1/76) at buoy B, the data developed by Moherek[23] (see Table 8) indicated that current velocity conditions favored erosion during April. Variation in mean sediment-size distributions and carbonate percentages during the period January-May 1976 suggested that the finer grained sediment was not being continuously eroded over the five-month period. According to Dr. T. Wright, (EEL, personal communication, 5 November 1975), an unannounced disposal in proximity to buoy B occurred between 18 February and 3 March 1976. This disposal of dredged materials at the buoy B site complicated the sedimentological data collected over the January-May 1976 period. The sediment change at the buoy B site may well be related to the introduction of the 18 February-3 March 1976 dredged materials. Carbonate percentages in proximity to buoy B over the period January-May 1976 decreased from January to March (33.5 to 27.5 percent). There was, however, a significant percentage increase northeast of the buoy B site during this period (5.0-26.8 percent).

105. Actual transport of the sand-sized material at the buoy B site has been documented by sampling of released dyed tracer sands. The predominant sediment transport direction 24 and 48 hr after release of tracer material was to the west, which coincides approximately with

prevailing current direction during that time period. Concomitant current data indicated that critical velocities necessary to transport sand-sized material were exceeded. A second tracer study, carried out at the buoy B site under higher velocity current conditions, indicated a greater degree of sediment transport, also to the southwest. Overall current direction measurements taken during the sand tracer experiments indicated that current activity is responsible for observed sediment transport.[20] Progressive current vector diagrams (Figures 68 and 70) indicated that, at least for the periods monitored, the prevailing current direction was to the southwest, and current velocity determinations (Figure 63) indicated that erosion and transport of material was the rule rather than the exception at the buoy B disposal site.

Buoy C Site

106. The mean grain size of sediments sampled near the buoy C site during the pilot study phase was about 6.5 Ø units (see Figure 18). January sediment data from the disposal mound (sample 12-3) indicated a significant increase in mean grain size (about 1.5 Ø). Away from the mound (samples 12-1, -2, -4, and -5), sediments became finer grained, approaching sizes found during the pilot project. Bottom sediments remained relatively coarser grained nearest the buoy throughout the five-month sampling period (January-May 1976; see Figures 34-36). Sediment coarsening was also evident southwest of the mound from samples collected in May relative to those collected in January.

107. The most significant aspect of the carbonate data collected in proximity to buoy C was the large increase in carbonate content in samples taken nearest the disposal mound crest (see Figures 43-45). By May 1976, carbonate concentrations had increased to about 70 percent from a January low of about 21 percent. West of the buoy sampling site, carbonate concentrations increased to about 100 percent, indicating that the coarser sediment fraction near the crest and to the west of the mound was composed predominantly of shell fragments. Sediment data indicated that the mound at buoy C was being eroded during the period

January-May 1976.

108. There were not sufficient current data from the buoy C site to determine the frequency of erosional velocities. Sediment and bathymetric data comparisons indicated that erosional forces were operational at buoy C. It is estimated that as much as 8300 m^3 of sediment were eroded. Relative to estimates for the buoy B site, this represented a small amount of material. It is also probable that during the postdisposal period of observation, a certain amount of sediment compaction occurred at each disposal site, and at least some decrease in the apparent volume of material at each site may have been due to compaction.

109. Finally, it is evident that current data are available for only a short period of time with limited areal extent. Assumptions made throughout this report have been based on available current data. It must be emphasized that the period of observation did not include any major storms, which would have produced greater erosion and transport of dredged materials.

Buoy D Site

110. The mean size of sediments collected during the period January-May 1976 was 5-6 Ø units; exceptions were from northwest of the mound during January and a general small increase in mean size nearest the mound crest (Figures 37-39).

111. Relative to the buoy B and C sites, the overall carbonate concentrations were highest near buoy D, probably reflecting the character of disposed materials. During the five-month period January-May 1976, carbonate percentages decreased from about 64 percent to about 31 percent (see Figures 45-47). This overall decrease was also evident away from the mound, suggesting that normal sedimentation was occurring at buoy D during the period January-May 1976.

112. Available bathymetric data indicated the mound crests at buoys C and D were about 13.5 m below mean sea level, while the buoy B site was covered with about 9.9 m of water. The deeper waters at buoys

C and D prevented the bottom sediments from being as greatly affected by wave energy and therefore not subjected to the relatively high wave-energy forces present at buoy B. Limited current data for the buoy B and D sites indicate bottom currents were slightly higher at site B relative to D (22-35 cm/sec vs. 18-22 cm/sec). Critical erosion velocities were exceeded at buoy B 53-81 percent of the time during which current data were obtained (3/17/76-3/24/76 and 4/8/76-5/1/76), whereas erosional processes prevailed at buoy D for 22-31 percent of the time (10/9/75-11/14/75, 3/17/76-4/7/76 and 4/8/76-5/3/76, see Table 3). Relative to buoy B, depositional frequencies were more common at buoy D, amounting to 18-20 percent of the 85-day period during which time current data were obtained.

Control Sites

113. Relative to pilot study samples, control block 27 underwent relatively little change. By January 1976, the mean sediment size of block 27 samples had increased from 9.7 Ø to about 8.8 Ø units (see Figures 18 and 55). This coarsening was probably related to higher energy winter conditions. During the subsequent five-month period, block 27 bottom sediments became progressively finer grained; by May 1976, the mean sediment size (9.2 Ø) approximated pilot study values. This decrease in grain size is likely due to deposition of finer grained sediments during the lower energy, milder weather conditions of the spring sampling period. The mean grain size of sampled sediments became slightly coarser grained at block 15 between the pilot study and May 1976.

114. From the sediment data it may be generalized that block 15 experienced net erosion during fall, winter, and early spring months; deposition occurred during the lower energy, summer period.

Summary of Hydrographic Results

115. Data acquired during the period February through May 1976

for the DMDS indicated:

a. Tides were mixed diurnal and ranged from 0.3 to 0.6 m in height.

b. High winds and storm activity affected both the near-shore sea level and near-bottom circulation patterns.

c. Maximum bottom current velocities and net offshore, or downcoast-directed, bottom flow appeared to be generated by strongly prevailing southeasterly winds (5 m/sec). Finally, according to Moherek,[23] near-bottom oscillatory flows induced by surface waves probably played a significant role in governing near-bottom sediment transport processes.

PART V: SUMMARY COMMENTS

116. It is evident that dredged materials have been eroded from buoy sites B and C. In contrast, apparent accretion occurred in the vicinity of buoy D. Sediment transport was toward the south-southwest at buoy B; actual sediment movement direction at buoy C is not known since current data are limited for the critical study period of fall 1975 to spring 1976.

117. Admittedly, interpretations are sketchy due to a number of reasons, including:

a. Limited useable field data due to wide geographic spread and timing of sample procurement.

b. Lack of sufficient baseline data. Little was known about the long-term natural sedimentological changes within the DMDS prior to initiation of disposal activities.

c. Lack of reliable sediment sampling locations due to variability and lack of reliability of navigational techniques employed.

d. Great variability in duplicate sediment samples taken at each sampling site.

e. Incomplete current data at each of the disposal sites.

f. Insufficient numbers of sampling stations located on disposal mounds. At least four stations should have been located on each of the three disposal material mounds, rather than one station on the mound with four additional stations around the perimeter.

g. Although the flume experiments provided estimates of current conditions required to erode or transport DMDS sediments, it should be kept in mind that each disposal mound would respond to short-term, as well as long-term, physical conditions. Sedimentologically, each mound would be dynamic; each change in sediment character would impose a new set of hydrodynamic conditions. It would be difficult, if not impossible, to determine the hydrodynamics responsible for eroding or transporting sediments because of the continuously varying sediment dynamics functioning at each mound.

h. Samples for flume studies should have included material collected from the hopper dredge as well as the disposal mound. Sampling only the mound biased the sample; an unknown amount of fine-grained material

would not be deposited at a disposal site due to removal by currents during disposal operations.

i. Since sampling techniques were not standardized, it is difficult to draw direct comparisons. At times samples were obtained with a spade corer; other times a Petersen or Van Veen grab sampler was used. Subsampling was also not standardized. From available data it was not possible to compare sediment variations related to the various sampling techniques employed.

j. Variation in subsamples is evident from data presented in Table 4. Note, for example, duplicate samples 2-5-A, 2-5-C, and 2-5-E. Mean size of these three samples varied from 2.63-11.00 Ø. The vessel was anchored while samples were collected for the January-June sampling period; therefore, much of the variability found is natural and not a function of changes in sampling location.

k. Few conclusions can be drawn about DMDS sediment distributions during the period June-September 1975, because predisposal sampling was concentrated outside the DMDS.

l. There is a lack of reliable information on the actual dredged material disposal operations. Field observations indicate dredged material was not always systematically disposed at prescribed locations. On occasion, sediment would become trapped in the hopper bins (as evidenced by aerial photographs) and would not be completely released at the prescribed disposal sites.

REFERENCES

1. U. S. Army Engineer Waterways Experiment Station, CE, "Field Research at the Offshore Dredge Material Disposal Site, Galveston, Texas," Information Exchange Bulletin, Vol D-76-1, May 1976, p. 2, Vicksburg, Miss.

2. Shepard, F. P., "Gulf Coast Barriers," Recent Sediments, Northwest Gulf of Mexico, F. P. Shepard, F. B. Phleger, and T. H. Van Andel, eds., American Association of Petroleum Geologists, Tulsa, Okla., 1960, pp 197-220.

3. Hoyt, J. H., "Barrier Island Formation," Geological Society of America Bulletin, Vol 78, 1967, pp 1125-1136.

4. Johnson, D. W., Shore Processes and Shoreline Development, Wiley, New York, 1919, p 584.

5. Henry, V. J., "Investigation of Shoreline-Like Features in the Galveston Bay Region, Texas," Proj. 24, p 76, 1956, Texas A&M College, Dept. of Oceanography, College Station, Tex.

6. LeBlanc, R. J. and Hodgson, W. D., "Origin and Development of the Texas Shoreline," Gulf Coast Association, Geological Society Transactions, Vol 9, 1959, pp 197-220.

7. Lankford, R. R. and Rogers, J. J., "Holocene Geology of the Galveston Bay Area," 1969, p 141, Houston Geological Society, Houston, Tex.

8. Davies, D. K., Etheridge, F. G., and Berg, R. R., "Recognition of Barrier Environments," American Association of Petroleum Geologists Bulletin, Vol 55, 1971, pp 550-565.

9. Greenman, N. N. and LeBlanc, R. J., "Recent Marine Sediments and Environments of Northwest Gulf of Mexico," American Association of Petroleum Geologists Bulletin, Vol 40, 1956, pp 813-846.

10. Curry, J. R., "Sediments and History of Holocene Transgression, Continental Shelf, Northwest Gulf of Mexico," Recent Sediments, Northwest Gulf of Mexico, F. P. Shepard, F. B. Phleger, and T. H. Van Andel, eds., American Association of Pertoleum Geologists, Tulsa, Okla, 1960, pp 221-266.

11. Scott, A. J. and Hayes, M. O., "Depositional Environments, South-Central Texas Coast, Field Trip Guidebook," Gulf Coast Association, Geological Society, 1964, p 170.

12. Bullard, F. M., "Source of Beach and River Sands on Gulf Coast of Texas," Geological Society of America Bulletin, Vol 53, 1942, pp 1021-1044.

13. Goldstein, A., Jr., "Sedimentary Petrologic Provinces of the Northern Gulf of Mexico," Journal of Sedimentary Petrology, Vol 12, 1942, pp 77-84.

14. Hsu, K. J., "Texture and Mineralogy of the Recent Sands of the Gulf Coast," Journal of Sedimentary Petrology, Vol 30, 1960, pp 380-403.

15. Van Andel, T. H. and Poole, D. M., "Sources of Recent Sediments in the Northern Gulf of Mexico," Journal of Sedimentary Petrology, Vol 30, 1960, pp 91-122.

16. Pinsak, A. D. and Murray, H. H., "Regional Clay Mineral Pattern in the Gulf of Mexico," Seventh National Conference on Clays and Clay Minerals, 1960, pp 162-177.

17. Folk, R. L., Petrology of Sedimentary Rocks, Hemphill, Tex., 1974 p 182.

18. Grim, R. E., "Modern Concepts of Clay Materials," Journal of Geology, Vol 50, No. 3, 1942, pp 225-275.

19 Hall, G., Sediment Transport Processes in the Nearshore Waters Adjacent to Galveston Island and Bolivar Peninsula, Unpublished Ph. D. Dissertation, Texas A&M University, College Station, Tex., 1976, p 325.

20. Bouma, A. H. and Huebner, G. L., "An Investigation of the Hydraulic Regime and Physical Nature of Sedimentation at the Offshore Disposal Site, Galveston, Texas" (for internal use), TAMRF Project 3205, Feb 1976, Texas A&M Research Foundation, College Station, Tex.; Prepared for U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss., under Contract No. DACW64-75-C-0069.

21. Bouma, A. H., "An Investigation of the Hydraulic Regime and Physical Nature of Sedimentation at the Offshore Disposal Site, Galveston, Texas" (for internal use), Baseline Data Report, TAMRF Project 3205, Dec. 1975, Texas A&M Research Foundation, College Station, Tex.; Prepared for U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss., under Contract No. DACW64-75-C-0069.

22. Harper, D. E., "Aquatic Disposal Field Investigations, Galveston Disposal Site; Appendix C: Investigation of the Effects of Dredging and Dredged Material on Disposal on the Offshore Biota," Contract Report No. DACW64-76-C-0038, 1977; Prepared for the U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

23. Moherek, A. J., "Flume Experiments on Sand, Silt and Clay Mixtures From the Offshore Dredged Material Disposal Site, Galveston, Texas," Contract Report No. DACW64-75-C-0069, Dec, 1976; Prepared for the U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

24. U. S. Naval Weather Service Command, "Summary of Synoptic Meteorologic Observations," Vol 4, Area 28, 1976, Washington, D. C.

SELECTED BIBLIOGRAPHY

Aibulatov, N. A., "New Investigation On the Movements of Sand Along Coasts", Bull. Oceanog. Comm. U.S.S.R., Vol. 1, 1957, pp. 72-80.

Applebaum, B. S., "Surface Microtextures of Deep Water Quartz Sands from Columbia and Sigsbee Basins", Unpublished Ph.D. Dissertation, Texas A&M University, College Station, Texas, 1974, p. 206.

Archie, G. E., "The Electrical Resistivity Log As An Aid in Determining Some Reservoir Characteristics", Trans. Am. Inst. Mining and Engineering, 1942, T. P. 1422, p. 146: 54-62.

Arlman, J. J., Santema, P. and Svasek J. N., "Movement of Bottom Sediment in Coastal Waters by Currents and Waves; Measurements with the Aid of Radioactive Tracers in the Netherlands", U. S. Army Beach Erosion Board, Tech. Mem. No. 105, 1958, p. 56.

Arlman, J. J., Svasek, J. N. and Verkerk, B., "The Use of Radioactive Isotopes for the Study of Littoral Drift", Dock Harbour Authority, Vol. 61, 1960, pp. 57-64.

Armstrong, F. A. J., "Inorganic Suspended Matter in Sea Water", Jour. Mar. Research, Vol. 17, 1958, pp. 23-24.

Atkins, E. R., Jr., and Smith, G. H., "The Significance of Particle Shape in Formation Resistivity Factor-Porosity Relationships", Jour. Petrol. Tech., 1961, p. 13: 285-291.

Barton, D. C., "Surface Geology of Coastal Southeast Texas", Am. Assoc. Petroleum Geologists, Vol. 14, 1930, pp. 1301-1319.

Bassin, N. J., "Analysis of Total Suspended Matter in the Caribbean Sea", Unpublished Ph.D. Dissertation, Texas A&M University, 1975, p. 106.

Beer, R. M. and Gorsline, D. S., "Distribution, Composition and Transport of Suspended Sediment in Redondo Submarine Canyon and Vicinity (Calif.)", Marine Geology, Vol. 10, 1971, pp. 153-175.

Berg, R. R. and Davies, D. K., "Origin of Lower Cretaceous Muddy Sandstone at Bell Creek Field, Montana", Am. Assoc. Petroleum Geologists Bull., Vol. 52, 1970, pp. 1888-1898.

Bernard, H. A., Major, C. F. and Parrott, B. S., "The Galveston Barrier Island and Environs - A Model for Predicting Reservoir Occurrence and Trend", Gulf Coast Assoc. Geol. Soc. Trans., Vol. 9, 1959, pp. 221-224.

Bernard, H. A., LeBlanc, R. J. and Major, C. F., "Recent and Pleistocene Geology of Southeast Texas, Field Excursion No. 3; In Geology of the Gulf Coast and Central Texas and Guide-Book of Excursions", Geol. Soc., America Ann. Mtg. Guide-Book, 1962, pp. 175-224.

Bernard, H. A. and LeBlanc, R. J., "Resume of the Quaternary Geology of the Northwestern Gulf of Mexico", The Quaternary of the United States, H. E. Wright and D. G. Frey, Eds., Princeton Univ. Press, Princeton, N. J., 1965, pp. 137-186.

Boldyrev, V. L., "Tests With Tracer Sand To Investigate Silting", Proc. Assoc. Maritime Proj. Min. Merchant Marine (U.S.S.R.), Vol. 3, 1956, pp. 63-71.

Bornhold, B. D., Mascle, J. R. and Harada, K., "Suspended Matter In Surface Waters of the Eastern Gulf of Guinea", Marine Geology, Vol. 14, 1973, pp. M21-M31.

Bouma, A. H., Methods for the Study of Sedimentary Structures, John Wiley & Sons, Inc., New York, N.Y., 1969, p. 458.

Bouma, A. H., et al., "Shipboard and Insitu. Electrical Resistivity Logging of Unconsolidated Marine Sediments", #TC 1351, 1971, Offshore Technology Conference.

Boyce, R. E., "Electrical Resistivity of Modern Marine Sediments From the Bering Sea", Jour. Geophys. Res., Vol. 73, 1968, pp. 4579-4766.

Bratteland, E. and Bruun, P., "Tracer Tests in the Middle North Sea", Proc. 14th Conf. Coastal Eng., 1974, pp. 978-990.

Bruun, P., "Tracing of Material Movement on Seashores", Shore and Beach, Vol. 30, 1962, pp. 10-15.

Caligny, A. F. H., "Experiences sur les Mouvements des Molecules Liquid des Ondes Courant, Considerees dans leur Mode D'Actions sur la Marcha des Navires", C.R. Acad. Sci., Paris, Vol. 87, 1878, pp. 1019-1023.

Carroll, D., "Clay Minerals: A Guide to Their X-ray Identification", Geological Soc. of America, Special Paper 126, 1970, p. 80.

Cernock, P. J., "Consolidation Characteristics and Related Physical Properties of Selected Sediments from the Gulf of Mexico", Unpublished M.S. Thesis, Texas A&M University, College Station, Texas, 1967, p. 137.

Cool, T., "Dredged-Material Disposal and Total Suspended Matter Offshore from Galveston, Texas", Unpublished M.S. Thesis, Texas A&M University, College Station, Texas, 1976, p. 160.

Coulter Electronics, Inc., Operators Manual for Coulter Counter Model TAII, Coulter Electronics, Inc., Hialeah, Fla., 1975, p. 88.

Coulthard, D., "Nearshore Sediments Off Galveston Island and Jetty System, Texas", Unpublished M.S. Thesis, Texas A&M University, College Station, Texas, 1976, p. 117.

Crickmore, M. J. and Lean, G. H., "The Measurement of Sand Transport by Means of Radioactive Tracers", Proc. Royal Soc. (London) Ser. A., Vol. 266, 1962, pp. 402-421.

Cummins, R. S. and Ingram, L. F., "Tracing Sediment Movement With Radioisotopes", Military Eng., Vol. 55, 1963, pp. 161-164.

Davidson, J., "Investigations of Sand Movement Using Radioactive Sand", Lund Univ. Studies Phys. Geograph. Ser. A, Vol. 12, 1958, pp. 69-126.

Dobb, P. H., "Effects of Wave Action On the Shape of Beach Gravel", Compass, Vol. 35, 1958, pp. 269-275.

Doll, H. G., "The Laterolog - A New Resistivity Logging Method With Eletrodes Using An Automatic Focussing System", Trans. Am. Instn. Min. Engs., Vol. 192, 1951, pp. 305-316.

Doll, H. G., "The Microlaterolog", Trans. Am. Instn. Min. Engs., Vol. 198, 1953, pp. 17-32.

Drake, D. E., "Suspended Sediment and Thermal Stratification in Santa Barbara Channel, California", Deep Sea Research, Vol. 18, 1971, pp. 763-769.

Einstein, H. A. and Krone, R. B., "Experiments to Determine Modes of Cohesive Sediment Transport in Salt Water", Jour. Geophy. Res., Vol. 67, 1962, pp. 1451-1461.

Eittreim, S., Ewing, M. and Thorndike, E. M., "Suspended Matter Along the Continental Margin of the North American Basin", Deep Sea Research, Vol. 16, 1969, pp. 613-624.

Ekman, V. W., "On the Influence of the Earth's Rotation on Ocean Currents", Ask. f. Mat. Astr. Ocn. Fysik. K. Sv. Vet. Ak., No. 11, Stockhelm, Vol. 2, 1905.

Emergy, K. O., Milliman, J. D. and Uchupi, E., "Physical Properties and Suspended Matter of Surface Waters in the Southeastern Atlantic Ocean", Journal of Sedimentary Petrology, Vol. 43, 1973, pp. 822-837.

Erchul, R. A. and Nacci, V. A., "Electrical Resistivity Measuring System for Porosity Determination of Marine Sediments", Marine Technology Soc. Jour., Vol. 6, No. 4, 1972, pp. 47-53.

Ewing, M. and Thorndike, E. M., "Suspended Matter in Deep Ocean Water", Science, Vol. 147, 1965, pp. 1291-1294.

Fisher, W. L., et al., Environmental Geologic Atlas of the Texas Coastal Zone, Galveston-Houston Area, Bur. of Econ. Geology, Univ. of Texas at Austin, 1972, p. 91.

Folk, R. L. and Ward, W. C., "Brazos River Bar: A Study in the Significance of Grain Size Parameters", Jour. Sed. Petrology, Vol. 27, 1957, pp. 3-27.

Folk, R. L., "A Review of Grain-Size Parameters", Sedimentology, Vol. 6, 1966, pp. 73-93.

Fox, D. L., Isaacs, J. D. and Cocoran, E. F., "Marine Leptopel, Its Recovery, Measurement and Distribution", Jour. Mar. Research, Vol. 2, 1952, pp. 29-46.

Gilbert, A., "Essai sur la Possibilite D'Employer Ag 110 Dans L'Etude du Transport du Sable Par la Mer", p. 63, 1954, Lab. Nacl. Eng. Civil Publ., Lisbon.

Goldberg, E. D., Baker, M. and Fox, D. L., "Microfiltration in Oceanographic Research", Jour. Mar. Research, Vol. 2, 1952, pp. 194-204.

Gordon, R. B., "Dispersion of Dredged Spoil Dumped in Near-Shore Waters", Estuarine and Coastal Marine Science, Vol. 2, 1974, pp. 349-358.

Graf, W. H., Hydraulics of Sediment Transport, McGraw-Hill, New York, N.Y., 1971, p. 513.

Griffin, G. M., "Regional Clay Mineral Facies - Products of Weathering Intensity and Current Distribution in the Northeastern Gulf of Mexico", Geological Soc. of America Bull., Vol. 73, 1962, pp. 737-768.

Griffin, G. M. and Manker, J. P., "Source and Mixing of Insoluble Clay-Minerals in a Shallow-Water Carbonate Environment Florida Bay", Jour. Sediment. Petrology, Vol. 41, 1971, pp. 302-306.

Grim, R. E., Clay Mineralogy, McGraw-Hill, New York, N.Y., 1968, p. 596.

Grim, R. E. and Johns, W. D., "Clay Mineral Investigation of Sediments in the Northern Gulf of Mexico", Proceedings Second Nat'l Conf. Clay and Clay Min., Nat'l Acad. Sci.-Nat'l Res. Council Pub. 327, 1954, pp. 81-102.

Guyod, H., "Fundamental Data for the Interpretation of Electric Logs", The Oil Weekly, Oct. 30, 1944, pp. 115: 38.

Harris, J. E., "Characterization of Suspended Matter in the Gulf of Mexico and Northern Caribbean Sea", Unpubl. M.S. Thesis, Texas A&M Univ., College Station, Tx., 1971, p. 145.

Hayes, M. O., "Hurricanes as Geological Agents: Case Studies of Hurricanes Carla, 1961, and Cindy, 1963", pp. 1-54, Report No. 61, 1967, Bureau of Economic Geology, University of Texas.

Hjulstrom, F., "Chap. II", The Morphological Activity of Rivers as Illustrated by Rivers Fyris, Vol. 25, Geol. Inst., Uppsala, 1935.

Hottman, W., "Areal Distribution of Clay Minerals and Their Relation to Physical Properties, Gulf of Mexico", Unpubl. M.S. Thesis, Texas A&M University, 1975, p. 55.

Ingle, J. C., Jr., "Measurement of Dispersion of Sand in the Foreshore Beach Environment by Means of Fluorescent Dyed Sand", Rept. Marine Geol., Dept. of Geol., Univ. Southern California, 1959, p. 620 (Unpublished).

Ingle, J. C., Jr., "A Study of Foreshore Sand Movement and Dispersion by Means of Fluorescent Dyed Sand", Proc. 1st Nat'l Coastal Shallow Water Res. Conf., D. S. Gorsline, Ed., 1961, pp. 649-651.

Ingle, J. C., Jr., "Study of Foreshore Sand Movement by Means of Fluorescent Dyed Sand", Geol. Soc. Am., Spec. Papers, Vol. 73, 1963, pp. 300-301.

Ingle, J. C., Jr., The Movement of Beach Sand, Elsevier Publishing Co., New York, N.Y., 1966, p. 221.

Inman, D. L., "Measures for Describing the Size Distribution of Sediments", Jour. Sed. Petrology, Vol. 22, 1952, pp. 125-145.

Inman, D. L. and Chamberlain, T. K., "Tracing Beach Sand Movement With Irradiated Quartz", J. Geophysical Res., Vol. 64, 1959, pp. 41-47.

Inose, S., et al., "The Field Experiment of Littoral Drift Using Radioactive Glass Sand", Proc. 1st Conf. Peaceful Uses Atomic Energy, Geneva, Switz., 1956, pp. 211-219.

Ionin, A. S., Kaplan, P. A. and Medvedev, V. S., "On Methods of Research in the Beach Zone of the Sea in the U.S.S.R.", Okeanologia, Vol. 1, 1961, pp. 148-162.

Jackson, M. L., Soil Chemical Analysis-Advanced Course, Prentice, New Jersey, 1954, p. 498.

Jackson, P. D., "An Electrical Resistivity Method for Evaluating the Insitu. Porosity of Clean Marine Sands", 1975, Dept. Phys. Ocn. Marine Sci. Lab., Univ. College of North Wales, Menai Bridge, Gwyneod, U.K.

Jacobs, M. B. and Ewing, M., "Mineralogy of Particulate Matter Suspended in Sea Water", Science, Vol. 149, 1956, pp. 179-180.

Jacobs, M. B. and Ewing, M., "Suspended Particulate Matter: Concentrations in the Major Oceans", Science, Vol. 163, 1969, pp. 380-383.

Jacobs, M. B. and Ewing, M., "Mineral Source and Transport in Waters of Mexico and Caribbean Sea", Science, Vol. 163, 1969, pp. 805-809.

Jerlov, N. G., "Maxima in the Vertical Distribution of Particles in the Sea", Deep-Sea Research, Vol. 5, 1959, pp. 173-184.

Johns, W. D. and Grim R. E., "Clay Mineral Composition of Recent Sediments from the Mississippi River Delta", Jour. Sed. Petrology, Vol. 28, 1958, pp. 186-199.

Jolliffe, I. P., "A Study of Sand Movements on the Lowestoft Sandbank Using Fluorescent Tracers", Geograph J., Vol. 129, 1963, pp. 480-493.

Jolliffe, I. P., "The Use of Tracers to Study Beach Movements and the Measure of Littoral Drift by a Fluorescent Technique", Rev. Geomorphol. Dyn., Vol. 12, 1967, pp. 81-96.

Kamel, A., "Littoral Studies Near San Francisco Using Tracer Techniques", Tech. Mem. 131, p. 86, 1962, U. S. Army Beach Erosion Board.

Kamel, A. M. and Johnson, J. W., "Tracing Coastal Sediment Movement by Naturally Radioactive Minerals", Proc. 8th Conf. Coastal Eng., 1962, pp. 324-330.

Keller, G. V., "The Role of Clays in the Electrical Conductivity of the Bradford Sand", Producers Monthly, No. 4, Feb., 1951, pp. 15: 23-28.

Kermabon, A., "Recent Developments in Deep Sea Electrical Resistivity Probings - Its Application to the Sedimentary Study of the Red Sea Hot Brines", Oceanology Int. 1972 Conf., Brighton, U.K., 1972, pp. 385-391.

Kermabon, A., Gehin, C. and Blavier, P., "A Deep Sea Electrical Resistivity Probe for Measuring Porosity and Density of Unconsolidated Sediments", Geophysics, Vol. 34, No. 4, 1969, pp. 554-571.

Kidson, C. and Carr, A. P., "Beach Drift Experiments at Bridewater Bay Somerset", Proc. Bristol Nature Soc., Vol. 30, 1961, pp. 163-180.

Kidson, C., Steers, J. A. and Flemming, N. C., "A Trial of the Potential Value of Aqualung Diving to Coastal Physiography On British Coasts", Geograph. J., Vol. 128, 1962, pp. 49-53.

Kimsey, J. B. and Temple, R. F., "Currents On the Continental Shelf of the Northwestern Gulf of Mexico", Annual Lab. Rept., pp. 23-27, 1962, U. S. Fish and Wildlife Biol. Lab., Galveston, Texas.

Kimsey, J. B. and Temple, R. F., "Currents On the Continental Shelf of the Northwestern Gulf of Mexico", Annual Lab. Rept., pp. 25-27, 1963, U. S. Fish and Wildlife Biol. Lab., Galv. Tx.

King, C. A. M., "Depth of Disturbance of Sand on Sea Beaches by Waves", Jour. Sed. Petrology, Vol. 21, 1951., pp. 131-140.

Kolbuszewski, J., "An Experimental Study of the Maximum and Minimum Porosities of Sands", Proc. Int. Conf. Soil Mechanics and Foundation Engineering, Rotterdam, V. I., 1948, pp. 158-165.

Komar, P. D. and Miller, M. C., "The Threshold of Sediment Movement Under Oscillatory Water Waves", Jour. Sed. Pet., Vol. 43, No. 4, 1973, pp. 1101-1110.

Krinsley, D. H. and Donahue, J., "Environmental Interpretation of Sand Grain Surface Textures by Electron Microscopy", Geol. Soc. America Bull., Vol. 79, 1968, pp. 743-748.

Krone, R. B., "Flume Studies of the Transport of Sediment in Estuarial Shoaling Processes", Contract No. DA-04-203, CIVENG-59-2, p. 108, 1962, U. S. Army Corps of Engineers.

Krone, R. B., et al., "Third Annual Report On the Silt Transport Studies Utilizing Radioisotopes", Ann. Rept. No. 3, p. 118, 1960, Hydraulic Eng. Lab., Sanit. Eng. Res. Lab., Univ. of California, Berkeley.

Krumbein, W. C., "The Use of Quartile Measures in Describing and Comparing Sediment", Amer. Jour. Sci., Vol. 32, 1936, pp. 98-111.

Krumbein, W. C. and Pettijohn, F. J., Manual of Sedimentary Petrology, Appleton-Century-Crofts, New York, 1938, p. 546.

Krynine, P. D., "Petrology and Genesis of the Third Bradford Sand", The Penn. State College M.I. Exp. Station Bull., No. 29, 1940.

Lambe, T. W., Soil Testing for Engineers, John Wiley & Sons, New York, 1951, p. 165.

Lisitzin, A. D., Sedimentation in the World Ocean, Ed. 17, Soc. Econ. Paleontologists and Mineralogists, Special Publ., 1972, p. 218.

Longard, J. R. and Banks, R. E., "Wind-Induced Vertical Movement of the Water on an Open Coast", Trans. Am. Geophys. Union, Vol. 33, No. 3, 1952, pp. 377-380.

Lonquet-Higgins, M. S. and Parkin, D. W., "Sea Waves and Beach Cusps", Geograph. J., Vol. 128, 1962, pp. 194-201.

Ludwick, J. D., "Tidal Currents and Zig-Zag Sand Shoals in a Wide Estuary Entrance", Geol. Soc. Am. Bull., Vol. 85, 1974, pp. 717-726.

Lunenburg, H., "Sediment Transport, Sedimentation and Erosion On the Outer Sands of the Weser Estuary (abst.)", Intern. Geol. Congress, 21st, Copenhagen, 1960, p. 247.

Lyle, W. M. and Smerdon, E. T., "Relation of Compaction and Other Soil Properties to Erosion and Resistance of Soils", Am. Soc. Agic. Eng., Vol. 8, 1965, pp. 419-421.

Malone, C. H., "Labeling of Sand Particles for Sediment Transport Studies Using Stable Isotopic Tracers", Ph.D. Dissertation (Unpublished), Texas A&M Univ., 1969, p. 111.

Manheim, F. T., Hathaway, J. C. and Uchupi, E., "Suspended Matter in Surface Waters of the Northern Gulf of Mexico", Limnology and Oceanography, Vol. 17, 1972, pp. 17-27.

Manheim, F. T., Meade, R. H. and Bond, G. C., "Suspended Matter in Surface Waters of the Atlantic Continental Margin from Cape Cod to Florida Keys", Science, Vol. 167, 1969, pp. 371-376.

Margolis, S. V., "Electron Micrography of Modern and Ancient Quartz Sand Grains", Coastal Research Notes, 2, 1966, pp. 7-8.

Marshall, C. E., The Colloid Chemistry of the Silicate Minerals, Academic Press, New York, N.Y., 1949.

Marshall, C. E. and Krinbill, C. A., "The Clays as Colloidal Electrolytes", Jour. of Phys. Chem., Vol. 46, 1942, p. 1077.

Mason, C. C. and Folk, R. L., "Differentiation of Beach, Dune and Aeolian Flat Environments by Size Analysis, Mustang Island, Texas", Jour. Sed. Petrology, Vol. 28, 1958, pp. 211-226.

May, E. B., "Environmental Effects of Hydraulic Dredging in Estuaries", Alabama Marine Resources Bulletin, No. 9, 1973, pp. 1-85.

McHenry, J. R. and McDowell, L. L., "The Use of Radioactive Tracers In Sedimentation Research", J. Geophys. Res., Vol. 67, 1962, pp. 1465-1471.

McManus, D. A. and Smyth, C. S., "Turbid Bottom Water on the Continental Shelf of the Northern Bering Sea", Journal of Sedimentary Petrology, Vol. 40, 1970, pp. 869-873.

Meade, R. H., "Landward Transport of Bottom Sediments in Estuaries of the Atlantic Coastal Plain", Journal of Sedimentary Petrology, Vol. 39, 1969, pp. 222-234.

Medvedev, V. C. and Aibulatov, N. A., "The Use of Marked Sand for the Study of the Transport of Marine Detritus", Ser. Geograph., Akad. Navk. U.S.S.R., Vol. 4, 1956, pp. 99-102.

Milliman, J. D., Summerhayes, C. P. and Barretto, H. T., "Oceanography and Suspended Matter Off the Amazon River", Journal of Sedimentary Petrology, Vol. 45, 1975, pp. 189-206.

Moore, D. G. and Scruton, P. C., "Minor Internal Structures of Some Recent Unconsolidated Sediments", Am. Assoc. Petroleum Geologists Bull., Vol. 41, 1957, pp. 2723-2751.

Murray, S. P., "Trajectories and Speeds of Wind-Driven Currents Near the Coast", J. Phys. Oceanogr., Vol. 5, 1975, pp. 347-360.

________________, "Observations on Wind, Tidal and Density-Driven Currents in the Vicinity of the Mississippi River Delta", Shelf Sediment Transport, Dowden, Stroudsburg, Penn., 1972, pp. 127-142.

Nelson, H. F. and Bray, E. E., Stratigraphy and History of the Holocene Sediments in the Sabine-High Island Area, Gulf of Mexico, Pub. 15, J. P. Morgan, Ed., Deltaic Sedimentation, Modern and Ancient, SEPM Spec., 1970, pp. 48-77.

Nikuradse, J., "Laws of Flow in Rough Pipes", Vol. 1292, pp. 1-62, 1933, Nat. Adv. Comm. Aeronautics Tech. Memo.

Nittrouer, C. A. and Sternberg, R. W., "The Fate of a Fine-Grained Dredge Spoils Deposit in a Tidal Inlet of Puget Sound, Washington", Journal of Sedimentary Petrology, Vol. 45, 1975, pp. 160-170.

Nowlin, W. D., Jr., "Winter Circulation Patterns and Property Distributions", Contributions in Oceanography, Henry, V. J. and R. Rezak (Eds.), Texas A&M Univ., College Station, Tx., 1971, pp. 3-51.

Otto, G. H. "A Modified Logarithmic Probability Graph for the Interpretation of Mechanical Analysis of Sediments", Jour. Sed. Petrology, Vol. 9, 1939, pp. 62-75.

Pantin, H. M., "Magnetic Concrete as an Artificial Tracer Material", New Zealand J. Geol. Geophys., Vol. 4, 1961, pp. 424-433.

Partheniades, E. and Mehta, A. J., "Rates of Deposition of Fine Cohesive Sediments in Turbulent Flows", Proceedings of the 14th Conference of the International Association for Hydraulic Research, Paris, Vol. 4, 1971, pp. 17-26.

Phillips, A. W., "Tracer Experiments at Spurn Head, Yorkshire, England", Shore and Beach, Vol. 31, 1963, pp. 30-35.

Phillips, O. M., The Dynamics of the Upper Ocean, Cambridge, New York, 1969, p. 261.

Pierce, J. W. and Stanley, D. J., "Suspended Sediment Concentration and Mineralogy in the Central and Western Mediterranean and Mineralogic Comparison with Bottom Sediment", Marine Geology, Vol. 19, 1975, pp. M15-M25.

Postma, H., "Sediment Transport and Sedimentation in the Estuarine Environment", Estuaries (G. H. Lauff Ed.), Amer. Assoc. Advmt. Sci., No. 83, 1967, pp. 158-179.

Prandtl, L. and Tietzens, O. G., Fundamentals of Hydro- and Aero-Mechanics, McGraw-Hill, New York, 1934, p. 270.

Putnam, J. L., et al., "Thames Siltation Investigation; Preliminary Experiment on the Use of Radioactive Tracers for Indicating Mud Movements", Internal Rept. No. 1576, p. 14, 1954, Atomic Energy Res. Estab. (Gt. Brit.).

Reineck, H. E. and Singh, I. B., Depositional Sedimentary Environments, Springer-Verlag, New York, 1973, p. 439.

Reynolds, O., "An Experimental Investigation of the Circumstances Which Determines Whether the Motion of Water Shall be Direct or Sinuous and the Law of Resistance in Parallel Channels", Phil. Trans. Am., Vol. 174, 1883, pp. 935-982.

Rhoads, D. C., "The Influence of Deposit-Feeding Benthos On Water Turbidity and Nutrient Recycling", Amer. Journal of Science, Vol. 273, 1973, pp. 1-22.

Rouse, H., Fluid Mechanics for Hydraulic Engineers, Dover, New York, 1961, p. 422.

Russell, R. C. H., "Use of Fluorescent Tracers for the Measurement of Littoral Drift", Proc. 7th Conf. Coastal Eng., Council Wave Res., Univ. California, Berkeley, Calif., 1960, pp. 418-444.

Sarma, T. P. and Iya, K. K., "Preparation of Artificial Silt for Tracer Studies near Bombay Harbour", J. Sci. Ind. Res. India, Vol. 19, 1960, pp. 99-101.

Sato, S., Ijima, T. and Tanaka, N., "A Study of Critical Depth and Mode of Sand Movement Using Radioactive Glass Sand", Proc. 8th Conf. Coastal Eng., 1962, pp. 304-323.

Scafe, D. W., "A Clay Mineral Investigation of Six Cores from the Gulf of Mexico", Unpubl. Ph.D. Dissertation, Texas A&M University, College Station, Tx., 1968, p. 76.

Scafe, D. W. and Kunze, G. W., "A Clay Mineral Investigation of Six Cores from the Gulf of Mexico", Marine Geology, Vol. 10, 1971, pp. 69-85.

Scruton, P. C. and Moore, D. G., "Distribution of Surface Turbidity Off Mississippi Delta", American Assoc. of Petroleum Geologists Bull., Vol. 37, 1953, pp. 1067-1074.

Sheldon, R. W. and Parsons, T. R., "On Some Applications of the Coulter Counter to Marine Research", Man. Rept. Series, Fish. Res. Bd. Canada, No. 214, 1966, p. 36.

Sheldon, R. W. and Sutcliffe, W. H., "Retention of Marine Particles by Screens and Filters", Lmn. and Ocean, Vol. 14, 1969, pp. 441-444.

Shideler, G. L., "A Comparison of Electronic Particle Counting and Pipette Techniques in Routine Mud Analysis", Open File Report No. 76-269, p. 20, 1975, U. S. Geol. Survey.

Shinohara, K., et al., "Sand Transport Along a Model Beach by Wave Action", Coastal Eng., Japan, Vol. 1, 1958, pp. 111-129.

Sidner, B., "Bathymetric and Sedimentological Data From the Galveston Offshore Dredged Disposal Site", Contract No. DACW-64-75-C-0069, In-House Working Document, prepared for the U. S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Miss., January-June, 1976.

Smerdon, E. T. and Beaslay, R. P., "The Tractive Force Theory Applied to Stability of Open Channels in Cohesive Soils", Agric. Exp. Stat. Res. Bull., Univ. Missouri, No. 715, 1969, p. 89.

Sollitt, C. K. and Crane, S. D., "Physical Changes in Estuarine Sediments Accompanying Channel Dredging", Proc. 12th Conf. Coastal Eng., 1972, pp. 1289-1303.

Spencer, D. W. and Sacks, P. L., "Some Aspects of the Distribution, Chemistry and Mineralogy of Suspended Matter in the Gulf of Maine", Marine Geology, Vol. 9, 1970, pp. 117-136.

Stevenson, H. S., "Vane Shear Determination of the Viscoelastic Shear Modulus of Submarine Sediments", Unpubl. M.S. Thesis, Texas A&M University, College Station, Tx., 1973, p. 124.

Stuiver, M. and Purpura, J. A., "Application of Fluorescent Coated Sand in Littoral Drift and Inlet Studies", Proc. 11th Conf. Coastal Eng., 1968, pp. 307-321.

Sundborg, F. A., "The River Kloralven, A Study of Fluvial Processes", Geogr. Amer. Agr., Vol. 37, 1956, pp. 125-316.

Sundby, B., "Distribution and Transport of Suspended Particulate Matter in the Gulf of St. Lawrence", Canadian Jour. Earth Sciences, Vol. 2, 1974, pp. 1517-1533.

Sverdrup, H. U., Johnson, M. W. and Fleming, R. H., The Oceans, Prentice-Hall, New Jersey, 1942, p. 1087.

Sweet, W. E., Jr., "Water Circulation Study in the Gulf of Mexico, A Review", Tech. Rept., p. 35, 1971, Texas A&M Univ., Dept. of Ocean., College Station, Tx.

Sweet, William E., "Electrical Resistivity Logging in Unconsolidated Sediments", Dissertation, Texas A&M Univ., Dept. of Ocean., College Station, Tx., 1972, p. 142.

Teleki, P. G., "Scanning Fluorescent Tracer Sand", Florida Univ. Coastal Eng. Lab. Mimeograph, 1963.

Teleki, P. G., "Wave Boundary Layers and Their Relation to Sediment Transport", Shelf Sediment Transport, Dowden, Stroudsburg, Penn., 1972, pp. 21-59.

Trask, P. D., Origin and Environment of Source Sediments of Petroleum, Gulf Pub. Co., Houston, 1932, p. 323.

Travenas, F. and LaRochelle, P., "Accuracy of Relative Density Measurements", Geotechnique, Vol. 22, No. 4, 1974, pp. 549-562.

Tucholke, B., "Determination of Montmorillonite in Small Samples and Implications for Suspended-matter Studies", Journal of Sedimentary Petrology, Vol. 44, 1975, pp. 2542-58.

U. S. Army Engineer Waterways Experiment Station, CE, "The Unified Soil Classification System", Technical Memorandum No. 3-357, March, 1953, Vol. 1, 3, Vicksburg, Miss.

Van Andel, T. H., Sources and Dispersion of Holocene Sediments, Northern Gulf of Mexico, Shepard, F. P., Phleger, F. B. and Van Andel, T. H., Eds., Recent Sediments, Northwest Gulf of Mexico, Am. Assoc. Petroleum Geologists, Tulsa, 1960, pp. 34-55.

Vendrov, S. L., et al., "Use of Luminofors to Study the Transport of Sediment Along Banks of Reservoirs", River Transport, U.S.S.R., Vol. 40, 1957, pp. 26-29.

Ward, M. and Sorensen, R. M., "A Method of Tracing Sediment Movement on the Texas Gulf Coast", Texas A&M Sea Grant Rept. 71-204, p. 111, 1970.

Weggel, J. R., Water Motion and Process of Sediment Entrainment, Shelf Sediment Transport, Dowden, Stroudsburg, Penn., 1972, pp. 1-20.

West, P. J., "Transportation of Cubical Bricks in a Cobble Beach Environment", Marine Geol. Rept. (Unpubl.), Univ. Southern California, Dept. of Geol., No. 522, 1949.

Wright, F. F., "The Development and Application of Flourescent Marking Technique for Tracing Sand Movements on Beach", Tech. Rept 2, 1962, Columbia Univ., Dept. of Geol.

Yasso, W. E., "Flourescent Coatings on Coarse Sediments; an Integrated System", Tech. Rept. 1, 1962, Columbia Univ., Dept. of Geol.

Zenkovitch, V. P., "Flourescent Substances as Tracers for Studying the Movement of Sand on the Sea Bed; Experiments Conducted in the U.S.S.R.", Dock and Harbour Authority, Vol. 40, 1960, pp. 280-283.

Table 1

Type, Location, Date, and Time of Current Meter Data Recovered

Type	Location	Date	Time, hr (CST)
Velocity Profiles	Buoy B	8 April, 1976	1000, 1120
		9 April, 1976	1055
		1 May, 1976	1150
	Buoy C	8 April, 1976	1430
		1-2 May, 1976	1400, 1600, 1800, 2000, 2200, 0000, 0200, 0400, 0600, 0800, 1000, 1200, 1400
	Buoy D	8 April, 1976	1245, 1330
		3 May, 1976	1200
Bottom Current Readings	Buoy B	17-24 March, 1976	1100-1315
		18 April-1 May, 1976	1200-0915
		1-11 May, 1976	1345-1930
	Buoy D	9 October-14 November 1975*	1600-1020
		17 March-8 April, 1976	1230-1030
		8 April-3 May, 1976	1415-0900
		3-11 May, 1976	1345-0715

* Reference 19.

Table 2

Sediment Data, Pilot Study

Sample (Block) Number	Shell Carbonate > 1 Ø	Sand Percent	Silt Percent	Clay Percent	$\bar{X}$ Ø	Median
1	9.18	98.54	1.46		2.68	2.65
2	1.24	46.57	19.77	33.66	7.03	4.70
3	0.42	14.75	32.04	53.21	9.70	8.45
4	2.13	54.59	17.72	27.69	9.16	3.80
5						
6	0.06	6.15	36.39	57.46	9.63	9.25
7	0.96	35.62	23.47	40.91	7.56	5.95
8	0.95	71.22	7.77	21.03	5.57	3.35
9	1.64	53.52	15.13	31.35	5.80	3.90
10	0.85	43.50	16.48	40.02	6.27	5.00
11	2.31	54.73	14.24	31.03	5.85	3.80
12						
13	0.62	33.09	23.21	43.70	7.43	6.90
14	3.81	54.85	9.35	35.80	5.93	3.75
15	3.37	39.03	19.08	41.88	7.05	6.70
16	0.21	46.68	23.41	29.91	6.10	4.40
17	1.03	37.07	24.24	38.69	7.80	5.70

(continued)

Table 2 (Concluded)

Sample (Block) Number	Shell Carbonate > 1 Ø	Sand Percent	Silt Percent	Clay Percent	$\bar{X}$ Ø	Median
18	1.05	57.80	13.21	28.99	5.95	3.80
19	0.18	5.18	34.56	60.26	9.40	9.50
20	0.91	21.75	22.39	55.86	8.20	8.90
21	2.15	35.34	19.68	44.98	7.16	6.70
22	0.13	37.65	19.68	42.67	7.47	6.65
23	0.22	28.44	26.46	45.10	7.63	6.75
24	0.52	17.59	33.40	49.01	9.18	7.90
25	0.06	4.67	32.29	63.04	9.25	9.60
26	0.24	3.57	27.99	68.44	9.25	10.00
27	0.02	3.18	28.47	68.35	9.71	10.00
28	0.09	12.74	27.92	59.34	8.68	9.30

Table 3

Percent Sand, Silt, and Clay; Buoy B Site; Pilot and Postdisposal Studies

	Sand Percent	Silt Percent	Clay Percent
Pilot Study	71.2	7.8	21.0
September	82.1	4.6	13.3
October	69.1	10.9	20.0
November	97.8*	1.4*	0.8*
December	9.9-98.7**	1.2-57.8**	0.04-32.3**

* Average of two samples

** Range of six samples

Table 4

Textural Data from Analysis of January, March and May, 1976 Sediment Samples

January, 1976

Sample No.	Mean	Median	Sorting	Skewness	Kurtosis	% Sand	% Silt	% Clay
(Buoy B Samples)								
2-1-E	2.17	2.80	1.45	-0.33	1.41	99.6	0.4	1.9
2-2-A	3.07	3.00	0.64	0.15	5.94	93.7	4.4	1.9
2-2-E	2.83	2.80	1.03	0.42	4.37	93.7	5.8	0.5
2-3-A	6.57	3.80	4.16	0.42	0.84	51.0	18.9	30.1
2-3-C	8.57	8.00	4.86	0.13	0.71	28.9	21.7	49.4
2-3-E	6.80	4.80	4.66	0.35	0.91	40.3	26.2	33.5
2-4-A	8.27	9.20	4.23	-0.05	0.69	26.5	14.9	58.6
2-4-C	8.67	9.40	4.37	-0.01	0.65	24.4	13.9	61.7
2-4-E	5.60	3.30	4.44	0.44	1.50	64.6	11.9	23.5
2-5-A	11.00	12.85	6.32	0.01	0.67	19.5	7.3	73.2
2-5-C	9.57	10.00	5.42			24.8	10.8	64.4
2-5-E	2.63	2.95	2.15	0.20	0.12	88.4	3.1	8.5
(Buoy C Samples)								
12-1-A	9.32	7.00	6.07	0.22	0.51	35.5	19.2	45.3
12-1-E	9.43	7.20	6.17	0.20	0.59	31.6	24.2	44.2
12-2-A	4.20	3.20	3.15	0.20	5.41	79.3	6.2	14.5
12-2-C	6.20	3.55	5.49	0.29	1.37	56.8	16.1	27.1
12-2-E	5.87	3.40	4.39	0.41	0.90	60.5	13.0	26.5
12-3-A	1.10	2.00	2.33	0.18	0.88	92.6	7.1	0.3
12-3-C	-0.03	-0.60	1.80	0.25	1.02	96.8	0.1	3.1
12-3-C	1.77	2.40	1.41	-0.32	0.10	98.5	1.5	
12-3-E	2.83	2.95	0.93	0.10	3.93	94.9	1.0	4.1
12-3-E	2.03	2.40	1.51	-0.21	1.49	95.3	4.1	0.6
12-4-A	3.17	1.20	5.17	0.29	0.14	72.1	4.5	23.4
12-4-C	7.80	6.10	5.48	0.27	0.73	40.7	18.2	41.1
12-4-E	5.80	3.80	3.74	0.33	0.73	50.8	17.0	32.2
12-5-A	9.30	9.00	5.07	0.09	0.81	16.2	26.2	57.6
12-5-C	8.50	9.60	3.14	-0.16	1.07	10.6	20.7	68.7
12-5-E	5.97	4.40	4.16	0.62	1.18	38.4	33.6	28.0

Table 4 (Continued)

(January Cont'd)

Sample No.	Mean	Median	Sorting	Skewness	Kurtosis	% Sand	% Silt	% Clay
(Buoy D Samples)								
14-1-A	3.60	3.00	2.92	0.15	6.51	77.3	8.0	14.7
14-1-C	3.03	3.00	1.40	0.34	6.07	87.1	6.0	6.9
14-1-E	4.83	3.25	3.38	0.40	2.12	70.9	8.8	20.3
14-2-C	7.10	4.90	4.75	0.35	1.32	25.5	47.0	27.5
14-2-E	6.07	4.80	5.04	0.29	0.99	36.1	35.2	27.7
14-3-C	5.37	2.80	2.91	0.09	1.49	85.0	4.2	10.8
14-4-E	6.20	4.20	4.73	0.25	0.88	48.2	17.8	34.0
14-5-A	7.47	5.80	5.04	0.27	0.86	33.6	27.7	38.7
14-5-E	6.87	5.00	4.76	0.33	1.01	34.2	35.9	29.9
(Block 15 Samples)								
15-1-A	4.80	3.20	4.00	0.44	4.63	73.2	9.3	17.5
15-1-C	7.00	4.60	4.98	0.35	0.80	45.8	17.1	37.1
15-1-E	2.90	3.00	0.24	-0.50	4.10	99.3	0.5	0.2
15-2-A	5.23	2.75	4.78	0.26	5.46	72.9	6.3	20.8
15-2-C	2.97	3.10	0.33			95.1	1.7	3.2
15-2-E	7.70	7.00	4.68	0.19	0.74	34.8	21.0	44.2
15-3-C	5.30	3.15	3.03	0.48	1.96	67.9	11.6	20.5
15-3-E	6.60	4.20	4.57	0.41	0.84	47.4	18.6	34.0
15-4-A	7.70	7.30	4.33	0.16	0.77	25.7	30.0	44.3
15-4-C	6.07	4.10	3.81	0.40	0.76	49.1	18.4	32.5
15-4-E	6.47	4.10	4.55	0.41	0.91	48.3	20.2	31.5
15-5-A	6.27	3.45	5.37	0.28	1.31	59.4	12.9	27.7
15-5-C	4.53	3.35	2.63	0.41	0.41	76.8	8.3	14.9
15-5-E	3.17	3.20	2.04	0.10	5.33	87.3	4.7	8.0
(Block 27 Samples)								
27-1-A	8.77	9.25	3.29	0.00	0.75	3.1	40.4	56.5
27-1-C	8.63	9.00	3.37	0.03	0.73	3.2	43.0	53.8
27-1-E	8.87	8.40	3.91	0.14	0.84	4.2	41.4	54.4
27-2-A	9.23	9.40	3.64	0.05	0.78	3.2	36.3	60.5
27-2-C	9.10	9.40	3.70	0.03	0.79	5.3	36.3	58.4
27-3-E	7.40	6.25	4.99	0.25	0.84	35.4	23.3	41.3
27-4-A	8.93	9.50	3.33	-0.09	0.84	7.4	30.8	61.8
27-4-C	8.80	9.00	3.68	0.02	0.83	8.7	34.2	57.1
27-4-E	9.03	9.00	3.59	0.10	0.77	1.1	43.4	55.5

Table 4 (Continued)

March, 1976

Sample No.	Mean	Median	Sorting	Skewness	Kurtosis	% Sand	% Silt	% Clay
(Buoy B Samples)								
2-1-A	5.60	3.70	2.94	0.45	2.03	37.9	17.7	44.4
2-1-C	5.10	3.00	4.71	0.27	1.54	59.4	10.5	30.1
2-1-E	4.66	3.60	3.66	0.26	5.12	60.4	37.2	2.4
2-2-E	5.00	3.00	4.83	0.29	2.22	73.3	7.7	19.0
2-3-C	8.30	9.10	5.23	0.08	0.80	23.2	21.7	55.1
2-3-E	9.30	9.00	4.83	0.11	0.72	26.3	19.6	54.1
2-4-A	6.97	5.30	4.51	0.32	0.91	42.3	23.1	34.6
2-4-C	8.30	8.30	4.44	0.09	0.60	28.5	22.4	49.1
2-5-A	6.03	3.90	4.54	0.40	1.00	56.4	17.0	26.6
2-5-C	6.20	4.00	4.69	0.39	1.03	52.2	20.0	27.8
2-5-E	6.93	5.20	5.04	0.81	0.32	48.0	14.8	37.2
(Buoy C Samples)								
12-1-C	8.43	8.00	5.42	0.24	1.24	31.7	20.8	47.5
12-1-E	8.20	7.60	5.10	0.25	0.91	30.1	24.4	45.5
12-2-A	5.40	5.30	3.91	0.33	0.93	62.8	11.6	25.6
12-2-C	5.10	-3.10	4.98	0.24	2.24	71.6	9.1	19.3
12-2-E	5.58	3.50	4.51	0.41	1.21	63.0	14.0	23.0
12-3-A	3.57	2.80	3.19	0.29	3.99	79.0	7.5	13.5
12-3-C	1.67	2.30	1.96	-0.53	1.21	95.2	2.3	2.5
12-3-E	3.23	2.10	5.39	0.43	1.12	72.7	10.8	16.5
12-4-A	9.50	9.20	4.73	0.09	0.89	10.2	33.9	55.9
12-4-C	8.60	8.00	4.93	0.15	0.85	10.2	37.8	52.0
12-5-C	7.50	5.70	5.21	0.27	0.81	41.7	21.3	37.0
12-5-E	5.60	3.70	4.04	0.02	0.22	60.0	14.6	25.4
(Buoy D Samples)								
14-1-A	4.03	3.90	2.87	0.30	1.02	56.7	22.3	25.0
14-1-C	5.23	3.30	4.66	0.19	1.24	60.8	14.0	25.2
14-1-E	8.50	8.00	5.01	0.20	0.88	21.6	28.0	50.4
14-2-A	4.33	3.70	3.57	0.13	2.89	57.4	24.8	17.8
14-2-C	6.87	5.20	5.15	0.54	0.99	41.7	22.8	35.5
14-2-E	6.27	4.90	4.19	0.57	1.04	36.1	34.8	29.1

Table 4 (Continued)

(March Cont'd)

Sample No.	Mean	Median	Sorting	Skewness	Kurtosis	% Sand	% Silt	% Clay
14-3-A	2.20	2.70	3.39	0.18	3.15	83.4	5.2	11.4
14-3-C	7.13	6.00	5.39	0.32	0.89	37.6	21.4	41.0
14-4-A	8.90	8.80	4.89	0.10	0.88	16.8	29.6	53.6
14-4-C	8.97	8.30	4.67	0.15	0.92	17.8	30.7	51.5
14-4-E	6.83	5.50	4.46	0.33	-0.42			
14-5-A	7.97	7.00	5.42	0.28	0.84	22.7	22.7	54.6
14-5-C	6.80	5.50	4.53	0.25	-0.82	41.0	23.6	35.4
14-5-E	4.20	2.90	5.47	0.22	1.06	63.0	14.0	23.0
(Block 15 Samples)								
15-1-A	3.63	3.10	1.86	0.71	3.28	82.5	5.7	11.8
15-1-C	3.27	3.30	0.78	0.22	1.87	93.9	1.5	4.6
15-1-E	3.07	3.00	0.50	0.16	0.94	98.0	1.0	1.0
15-2-A	4.87	3.40	3.33	0.40	4.51	78.6	6.1	15.3
15-3-A	3.23	3.20	1.37	0.38	4.22	90.7	3.9	5.4
15-3-C	4.17	3.40	2.46	0.39	4.14	76.5	9.1	14.4
15-3-E	6.00	3.80	4.08	0.82	0.98	62.4	10.6	27.0
15-4-A	3.00	5.60	0.49	0.00	1.09	35.0	29.8	35.2
15-4-E	7.03	5.25	4.55	0.35	0.98	39.6	25.1	35.3
15-5-A	5.77	3.85	3.67	0.41	1.09	60.0	16.0	25.0
15-5-C	6.93	6.60	3.96	0.30	0.82	34.0	26.3	39.7
15-5-E	5.93	4.00	4.15	0.38	1.17	49.8	24.8	25.4
(Block 27 Samples)								
27-1-A	11.00	10.10	4.82	0.08	0.76	3.6	27.5	68.9
27-1-C	8.93	8.50	4.45	0.16	0.87	7.8	31.1	61.1
27-2-A	9.87	9.70	3.33	0.09	0.97	3.0	24.8	72.2
27-2-C	8.83	8.00	3.83	0.21	0.80	11.0	39.8	49.2
27-2-E	9.17	9.10	3.84	0.10	0.90	12.8	29.4	57.8
27-3-A	8.23	8.10	3.90	0.08	0.90	9.9	32.7	57.4
27-3-C	9.07	8.40	4.07	0.18	0.94	10.5	37.5	52.0
27-4-A	9.40	9.40	3.37	0.11	1.17	2.7	28.1	69.2
27-4-C	9.50	9.50	3.31	0.09	0.94	2.8	28.4	69.8
27-4-E	8.77	8.60	3.35	0.11	0.93	1.8	33.0	65.2
27-5-A	7.53	6.70	4.06	0.18	0.95			
27-5-C	9.33	9.30	3.63	0.09	0.82	7.1	32.4	60.5
27-5-E	7.93	7.50	3.72	0.16	0.94	8.7	38.5	52.8

Table 4 (Continued)

May, 1976

Sample No.	Mean	Median	Sorting	Skewness	Kurtosis	% Sand	% Silt	% Clay
(Buoy B Samples)								
2-1-A	2.90	3.00	0.78	-0.29	1.69	98.7	0.5	0.8
2-1-C	6.73	3.90	5.12	0.39	0.80	53.0	9.9	37.1
2-1-E	2.97	2.90	1.12	0.15	2.32	90.9	3.0	6.1
2-2-A	5.37	3.40	4.20	0.39	1.12	67.6	7.5	24.9
2-2-C	8.40	7.60	5.16	0.17	0.81	35.5	16.4	48.1
2-2-E	8.20	7.50	5.35	0.31	-0.40	37.4	15.1	47.5
2-3-A	2.80	2.70	0.55	1.23	0.17	95.5	1.9	2.6
2-3-C	2.97	2.80	1.62	0.40	3.73	88.6	4.3	7.1
2-3-E	6.87	3.90	4.97	0.41	0.89	54.7	5.9	39.4
2-4-A	9.13	9.50	4.60	0.02	0.96	15.9	20.2	63.9
2-4-C	6.10	3.80	4.52	0.39	0.91	55.1	13.9	31.0
2-4-E	6.73	4.00	5.09	0.39	0.84	49.6	12.9	37.5
2-5-A	2.90	2.80	1.65	0.30	3.83	91.2	2.5	6.3
2-5-E	2.97	2.90	1.71	0.23	4.10	89.9	3.8	6.3
(Buoy C Samples)								
12-1-A	5.93	3.80	4.49	0.39	0.95	53.3	19.0	27.7
12-1-C	5.21	3.70	6.24	0.41	3.24	55.3	27.2	17.5
12-1-E	5.47	3.60	4.16	0.40	1.36	61.1	16.3	22.6
12-2-A	6.40	4.30	4.78	0.28	-0.33	47.0	23.3	29.7
12-2-E	5.87	3.70	4.65	0.36	1.09	57.3	16.2	26.5
12-3-A	0.17	0.00	1.26	0.14	1.08	97.2	0.5	2.3
12-3-C	0.50	0.20	2.92	0.32	1.52	87.9	4.2	7.9
12-3-E	0.17	-0.20	3.02	0.35	1.35	88.5	4.6	6.9
12-4-A	1.70	-0.90	5.53	0.45	1.82	82.9	1.6	15.5
12-4-C	1.90	2.50	2.28	0.01	1.72	93.3	2.2	4.5
12-5-A	7.87	7.00	4.56	0.18	0.89	19.9	37.9	42.2
(Buoy D Samples)								
14-1-A	3.70	2.30	5.64	0.28	1.45	72.7	7.2	20.1
14-1-C	3.90	2.60	3.64	0.33	3.66	78.9	6.3	14.8
14-1-E	9.53	10.30	2.92	-0.06	1.08	6.3	19.0	74.7
14-2-A	5.43	3.30	5.13	0.22	1.59	61.0	15.9	23.1

Table 4 (Concluded)

(May Cont'd)

Sample No.	Mean	Median	Sorting	Skewness	Kurtosis	% Sand	% Silt	% Clay
14-2-C	5.93	4.00	5.13	0.24	1.30	49.7	24.1	26.2
14-2-E	8.30	7.70	5.29	0.15	0.73	27.4	25.0	47.6
14-3-A	4.87	3.00	5.93	0.20	1.21	63.2	11.3	25.5
14-3-C	4.87	3.00	0.49	0.00	0.13	51.4	15.2	33.4
14-3-E	5.20	3.00	4.84	0.32	1.06	61.4	13.3	25.3
(Block 15 Samples)								
15-1-A	2.50	2.70	2.22	0.07	4.10	93.1	1.5	5.4
15-1-C	8.87	7.00	6.01	0.19	0.66	41.5	12.0	46.5
15-2-A	2.80	2.70	1.46	0.17	3.84	93.1	2.5	4.4
15-2-C	2.60	2.60	0.90	-0.24	2.94	97.7	0.2	2.1
15-2-E	6.23	3.40	4.98	0.42	0.96	64.6	6.8	28.6
15-3-A	4.37	3.00	3.49	0.45	4.60	77.4	7.3	15.3
15-3-C	6.10	3.60	4.70	0.42	5.36	64.5	9.2	26.3
15-3-E	3.00	3.00	0.49	0.00	0.13	97.8	1.3	0.9
15-4-A	4.43	3.10	3.21	0.43	3.62	77.4	7.5	15.1
15-4-C	5.80	5.00	3.13	0.29	1.11	38.4	21.8	39.8
15-4-E	5.20	3.60	3.90	0.42	2.97	70.2	12.8	17.0
15-5-A	3.33	3.00	2.28	0.41	4.25	82.4	8.6	9.0
15-5-C	4.97	3.40	3.75	0.41	5.22	72.3	10.4	17.3
(Block 27 Samples)								
27-1-A	9.10	8.70	4.55	0.14	0.87	10.2	35.5	54.3
27-1-C	9.50	9.30	4.63	0.09	0.81	9.6	29.5	60.9
27-1-E	8.77	8.00	4.61	0.16	0.95	9.8	41.2	49.0
27-2-A	10.10	9.60	4.68	0.09	0.81	5.5	3[illegible].6	60.9
27-2-C	7.67	6.00	5.29	0.31	0.40	36.0	21.8	42.2
27-2-E	7.17	5.10	5.13	0.32	0.81	43.6	19.6	36.8
27-3-A	9.53	9.00	4.68	0.09	0.81	9.1	33.4	57.5
27-3-C	9.57	9.00	4.82	0.11	0.81	10.0	34.0	56.0
27-3-E	9.73	9.20	4.71	0.10	0.83	8.0	33.3	58.7
27-4-A	9.73	9.20	4.68	0.11	0.82	6.9	33.8	59.3
27-4-C	9.90	9.90	4.25	0.04	0.81	5.5	31.6	62.9
27-4-E	9.20	9.00	4.39	0.07	0.81	10.2	35.6	54.2
27-5-A	9.47	9.00	4.44	0.14	0.83	5.0	38.5	56.5
27-5-C	9.10	8.70	4.31	0.11	0.77	7.0	39.2	53.8
27-5-E	8.67	8.70	4.79			18.8	27.1	54.1

Table 5

Percent Carbonate for January, March and May Sediment Samples, DMDS

Sample	Carbonate, percent		
	January	March	May
Buoy B Site			
2-1	33.5	27.5	1.8
2-2	5.0	26.8	1.9
2-3	2.4	3.2	6.1
2-4	4.3	1.9	2.5
2-5	5.3	2.7	2.0
Buoy C Site			
12-1	18.6	1.8	5.5
12-2	37.7	3.3	1.9
12-3	20.8	37.8	66.9
12-4	4.0	1.8	99.9
12-5	3.1	9.0	2.1
Buoy D Site			
14-1	28.0	1.5	26.8
14-2	2.2	2.0	2.0
14-3	63.9	50.4	31.0
14-4	24.4	1.6	3.0
14-5	1.8	3.6	2.8
Control Block 15			
15-1	6.5	2.2	2.1
15-2	2.8	6.0	3.1
15-3	1.5	22.7	1.2
15-4	1.3	2.0	1.3
15-5	1.2	2.4	2.9

(continued)

Table 5 (Concluded)

Sample	Carbonate, percent January	March	May
Control Block 27			
27-1	1.2	1.3	1.1
27-2	1.2	1.8	1.0
27-3	1.1	1.3	2.2
27-4	1.2	1.0	
27-5	4.3	1.5	1.0

Table 6

Geotechnical Properties of Samples from Control Blocks 15 and 27 and Buoys C and D Sites

	Buoy D	Block 27	Buoy C	Block 15	
Percent Sand	51.2	18.5	63.7	50.5	Dispersed
Percent Silt	11.7	35.9	13.5	22.6	Grain-size
Percent Clay	37.1	45.6	22.8	24.9	Analysis
Water Content (W) (% dry weight)	61.9	117.6	70.1	90.4	
Bulk Density (gm/cm^3)	1.64	1.41	1.59	1.49	
Void Ratio (e)	1.67	3.13	1.87	2.46	
Specific Gravity (G)	2.70	2.67	2.67	2.71	
Remolded Shear Strength (C_u)($kPa\times10^{-5}$)	11.08	6.72	3.09	3.36	
Percent Organic Content	2.91	4.14	1.84	3.13	
Liquid Limit (W_L)	56.0	101.5	40.5	66.5	Valid for
Plastic Limit (W_P)	48.2	63.5	40.0	51.4	>1.25 ϕ
Plasticity Index (I_P)	7.8	38.0	0.5	15.1	Fraction
					Only

Table 7

Sand, Silt, and Clay Percentages and Grain-Size Distribution Parameters Determined From Non-Dispersed Analysis

	Buoy C	Buoy D	Block 15	Block 27
Percent Sand	64.90	64.30	36.70	13.60
Percent Silt	16.50	11.90	30.40	55.10
Percent Clay	18.60	23.80	32.90	31.30
M_z (Ø)	4.80	3.77	6.83	6.53
$Ø_I$	2.61	4.14	4.20	2.50
Sk_I	0.78	0.21	0.60	0.31

Table 8

Net Drift and Direction of Bottom Currents as Determined From the Progressive Vector Diagrams

Location	Dates	Duration of Observation Period (Days)	Net Drift (km)	Net Direction
Buoy B	3/17/76-3/24/76	7	195	SW
	4/8/76-5/1/76	24	417	SW
Buoy D	10/9/75-11/14/75	37	260	SW
	3/17/76-4/7/76	22	390	SE
	4/8/76-5/3/76	26	277	SE

Table 9

Wind Speed Versus Sea Height

Sea Height, m	Wind Speed, m/sec-Occurrence, Percent					
	0.5-1.5	>1.5-5.0	>5.0-10.8	>10.8-17.0	>17.0-24.2	Percent
<.25	1.6	6.6	0.1			8.3
.25-.75	0.9	19.4	8.8			29.1
.75-1.25	0.1	10.8	20.0	0.9		31.8
1.25-1.75		2.2	12.5	2.0	0.1	16.8
1.75-2.25		0.3	4.4	2.2		6.9
2.25-2.75			1.2	1.4		2.6
2.75-3.25			0.1	0.7	0.1	0.9
3.25-3.75				0.4		0.4
3.75-4.75				0.2		0.2
Total Percent	2.6	39.3	47.1	7.8	0.2	97.0

Table 10

Percent Frequency of Wave Height (m) Versus Wave Period (sec)

(sec) Period	Wave Height <.25	.25-.75	.75-1.25	1.25-1.75	1.75-2.25	2.25-2.75	2.75-3.25	3.25-3.75	3.75-4.75
<6	7.8	24.0	21.1	7.2	2.1	.7	.2	.1	
6-7	.4	2.3	8.0	7.4	3.0	1.1	.3	.2	.1
8-9	.1	1.4	1.4	1.6	1.3	.5	.3	.1	.1
10-11		1.4	1.1	.4	.4	.3	.1		
12-13			.2	.1	.1				
>13				.1					
Total Percent	8.3	29.1	31.8	16.8	6.9	2.6	0.9	0.4	0.2

Table 11

Relative Percentage Frequency of Deposition, Transport, and Erosion at Bucys B and D

Buoy and Date of Observation	Duration of Observation Period (Days)	Deposition Percent Time $\bar{U} < 12$ (cm/sec)	Transport Percent Time $12 < \bar{U} \leq 28$	Erosion Percent Time $\bar{U} > 28$ (cm/sec)
Buoy B				
3/17/76-3/24/76	7	3	16	81
4/8/76-5/1/76	24	3	44	53
Buoy D				
10/9/75-11/14/75	37	19	59	22
3/17/76-4/7/76	22	20	49	31
4/8/76-5/3/76	26	18	56	26

APPENDIX A':

PERCENT FREQUENCY OF WIND SPEED (m/sec) AND DIRECTION VERSUS SEA HEIGHTS (m)

Height, m	0.5-1.5	>1.5-5.0	>5.0-10.8	>10.8-17.0	Percent
		N			
<.25	.2	.6			.8
.25-.75	.1	1.5	.7		2.3
.75-1.25		.9	2.0	.2	3.1
1.25-1.75		.2	1.6	.6	2.4
1.75-2.25			.8	.6	1.4
2.25-2.75			.3	.4	.7
2.75-3.25				.2	.2
3.25-3.75				.1	.1
3.75-4.75				.1	.1
Total Percent	.3	3.2	5.4	2.2	11.1
		NE			
<.25	.2	.7			.9
.25-.75		2.4	.9		3.3
.75-1.25		1.3	3.0	.1	4.4
1.25-1.75		.3	2.0	.3	2.6
1.75-2.25			.6	.4	1.0
2.25-2.75			.2	.3	.5
2.75-3.25				.1	.1
3.25-3.75				.1	.1
3.75-4.75					
Total Percent	.2	4.7	6.7	1.3	12.9
		E			
<.25	.2	1.1			1.3
.25-.75	.2	3.9	1.7		5.8
.75-1.25		2.4	4.0	.2	6.6
1.25-1.75		.5	2.4	.3	3.2
1.75-2.25		.1	.8	.3	1.2
2.25-2.75			.2	.2	.4

(continued)

Appendix A' (Continued)

Height (m)	0.5-1.5	>1.5-5.0	>5.0-10.8	>10.8-17.0	Percent
2.75-3.25				.1	.1
3.25-3.75				.1	.1
3.75-4.75					
Total Percent	.4	8.0	9.1	1.2	18.7
			SE		
<.25	.3	1.5			1.8
.25-.75	.1	4.8	2.4		7.3
.75-1.25	.1	3.0	5.7	.2	9.0
1.25-1.75		.6	3.4	.3	4.3
1.75-2.25		.1	1.1	.3	1.5
2.25-2.75			.3	.1	.4
2.75-3.25			.1	.1	.2
3.25-3.75					
3.75-4.75					
Total Percent	.5	10.0	13.0	1.0	24.5
			S		
<.25	.4	1.3	.1		1.8
.25-.75	.2	3.6	1.6		5.4
.75-1.25		1.9	3.5	.1	5.5
1.25-1.75		.3	1.9	.3	2.5
1.75-2.25		.1	.6	.2	.9
2.25-2.75			.1	.2	.3
2.75-3.25				.1	.1
3.25-3.75					
3.75-4.75					
Total Percent	.6	7.2	7.8	.9	16.5
			SW		
<.25	.1	.5			.6
.25-.75	.1	1.4	.9		2.4
.75-1.25		.6	.7		1.3
1.25-1.75		.1	.4		.5

(continued)

Appendix A' (Concluded)

Height (m)	0.5-1.5	>1.5-5.0	>5.0-10.8	>10.8-17.0	Percent
1.75-2.25			.1		.1
2.25-2.75			.1		.1
2.75-3.25					
3.25-3.75					
3.75-4.75					
Total Percent	.2	2.6	2.2		5.0
		W			
<.25	.1	.5			.6
.25-.75	.1	.9	.3		1.3
.75-1.25		.3	.4		.7
1.25-1.75		.1	.3		.4
1.75-2.25			.1	.1	.2
2.25-2.75					
2.75-3.25					
3.25-3.75					
3.75-4.75					
Total Percent	.2	1.8	1.1	.1	3.2
		NW			
<.25	.1	.4			.5
.25-.75	.1	.9	.3		1.3
.75-1.25		.4	.7	.1	1.2
1.25-1.75		.1	.5	.2	.8
1.75-2.25			.3	.3	.6
2.25-2.75				.2	.2
2.75-3.25				.1	.1
3.25-3.75				.1	.1
3.75-4.75				.1	.1
Total Percent	.2	1.8	1.8	1.1	4.9

TOTAL PERCENT = 96.8

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: *Facsimile Catalog Cards for Laboratory Technical Publications*, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Estes, E L

Aquatic disposal field investigations, Galveston, Texas, offshore disposal site; Appendix A: Investigation of the hydraulic regime and physical nature of sedimentation / by E. L. Estes, R. J. Scrudato, Texas A&M University, Moody College, Department of Marine Sciences, College Station, Texas. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1977.

134, [18], 3 p. : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; D-77-20, Appendix A)

Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C., under Contract No. DACW64-75-C-0069 (DMRP Work Unit No. 1A09A)

References: p. 120-134.

1. Dredged material disposal. 2. Field investigations. 3. Galveston Offshore Dredged Material Disposal Site. 4. Geologic processes. 5. Geological sedimentation. 6. Hydraulic regimen.

(Continued on next card)

Estes, E L

Aquatic disposal field investigations, Galveston, Texas, offshore disposal site; Appendix A: Investigation of the hydraulic regime and physical nature of sedimentation ... 1977. (Card 2)

7. Sedimentation. 8. Waste disposal sites. I. Scrudato, R. J., joint author. II. United States. Army. Corps of Engineers. III. Texas. A & M University, College Station. Moody College. Dept. of Marine Sciences. IV. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; D-77-20, Appendix A.